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ENVIRONMENT HOUSE LIMITED

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TABLE OF CONTENTS

INTRODUCTION 1

SECTION 1: BACKGROUND ON GOLD MINING 5

1.1 INTRODUCTION 5
1.2 GOLD MINES IN THE TIMMINS-KIRKLAND LAKE AREA 6
1.3 LITERATURE REVIEW 9
1.3.1 Geology and Mineralogy 9
1.3.2 Tailings Management 10
1.3.3 Cyanide in Effluents 11
1.3.4 Other Parameters in Effluents 14
1.3.5 Sludges 15
1.3.6 Heap Leaching 15
1.3.7 Waste Rock 16
1.3.8 Decommissioning and Close Out 17

SECTION 2: REVIEW OF REGULATORY DOCUMENTS 21

2.1 INTRODUCTION 21
2.2 THE REGULATORY ENVIRONMENT 21
2.2.1 Ontario Ministry of the Environment 21
2.2.2 Ontario Ministry of Northern Development and Mines 25
2.2.3 Environment Canada 27
2.3 REVIEW OF THE REGULATORY DOCUMENTS 28
2.3.1 Approvals Granted Under Section 24 of OWRA 30
2.3.2 Mineral Industries Information Sheets 37
2.3.3 Supporting Documentation for Section 24 Approvals 38
2.3.4 Certificate of Approval under Regulation 308 43
2.3.5 Permits to Manage Solid Wastes 43
2.4 IDENTIFICATION OF ENVIRONMENTAL ISSUES 44
2.4.1 Geology 45
2.4.2 Tailings 45
2.4.3 Effluents 45
2.4.4 Receiving Water Quality 47
2.4.5 Heap Leaching 48
2.4.6 Sludges 48
2.4.7 Waste Rock 48
2.4.8 Decommissioning 49
2.4.9 Air Emissions 50
2.4.10 Solid Wastes 50

SECTION 3: ISSUES AND TECHNOLOGY-BASED OPPORTUNITIES 53

3.1 INTRODUCTION 53
3.2 RANKING OF ENVIRONMENTAL ISSUES 53
3.2.1 Decommissioning 56
3.2.2 Receiving Water Bodies 56
3.2.3 Effluents 57
3.2.4 Tailings 57
3.2.5 Geology 57
3.2.6 Waste Rock 58
3.2.7 Solid Wastes 58
3.2.8 Sludges 58
3.2.9 Heap Leaching 58
3.2.10 Air emissions 59
3.3 TECHNOLOGY-BASED OPPORTUNITIES 59
3.3.1 Decommissioning of Entire Mine Property 59
3.3.2 Effects Monitoring in Receiving Water Bodies 61
3.3.3 Production of Non-toxic Effluents 62
3.3.4 Long-term stability of tailings 67
3.4 RECOMMENDATIONS 69
3.4.1 Decommissioning 69
3.4.2 Mill Effluents 70
3.4.3 Gold Tailings 70

LIST OF TABLES

TABLE 2.1: ONTARIO PWQO FOR SELECTED PARAMETERS 22
TABLE 2.2: ONTARIO EFFLUENT GUIDELINES 23
TABLE 2.3: RANKING OF EFFLUENT PARAMETERS 24
TABLE 2.4: FEDERAL EFFLUENT STANDARDS 27
TABLE 2.5: REGULATORY DOCUMENTS REVIEWED 29
TABLE 2.6: EFFLUENT CONCENTRATION LIMITS IN CERTIFICATES OF APPROVAL 31
TABLE 2.7: EFFLUENT MONITORING REQUIREMENTS IN CERTIFICATES OF APPROVAL 33
TABLE 2.8: SULPHIDE MINERALS IN ORE BODIES 37
TABLE 2.9: SUMMARY OF SECTION 24 SUPPORTING DOCUMENTATION 41

TABLE 3.1: RANKING OF ENVIRONMENTAL ISSUES 55

SUMMARY

This study identifies and ranks the relative importance of environmental issues associated with gold mining based on a review of the scientific literature and the regulatory documents issued to gold mines in the Timmins-Kirkland Lake area of Ontario. The review identified four issues which may be cause for environmental concern, namely:

- Decommissioning of the entire mine property;
- Effects monitoring in receiving water bodies;
- Production of non-toxic effluents; and
- Long-term stability of tailings.

These issues were classified as significant because either (a) there is a need for new or improved technology or (b) there are substantial gaps in what is known about their possible environmental impacts. The study suggests a number of technology developments, research programs or laboratory studies which could be initiated by CANMET to address these deficiencies. These initiatives would assist a major sector of Canada's resource-based industry by fostering technologies which afford a high degree of environmental protection, consistent with sustainable development.

RÉSUMÉ

Cette étude identifie et évalue l'importance relative des problèmes environnementaux associés à l'extraction de l'or. Elle s'appuie sur une analyse de la littérature scientifique dans le domaine et sur les documents réglementaires distribués aux mines de la région de Timmins-Kirkland Lake, en Ontario. Quatre situations susceptibles d'être préoccupantes sur le plan environmental y sont examinées:

- la fermature de la mine;
- la surveillance des effets des contaminants déversés dans les cours d'eau;
- la production d'effluents non toxiques; et
- la stabilité à long terme des résidus solides.

Ces situations ont été jugées importantes de fait (a) qu'elles révèlent un besoin de technologies nouvelles ou améliorées ou (b) que leur impact sur l'environment est encore mal connu. L'étude propose plusieurs perfectionnements ou innovations techniques, programmes de recherche et études de laboratoire qui pourrait entreprendre CANMET dans le but de combler ces lacunes. De tels travaux aideraient un vaste secteur de l'industrie canadienne des resources naturelles en favorisant l'élaboration de technologies protectrices de l'environment et compatibles avec le développement durable.

INTRODUCTION

Environment House Limited was retained by CANMET to develop an environmental profile of the gold mining industry using the Timmins-Kirkland Lake area of Ontario as an example. The goal of the study is to identify the role CANMET might play in developing new technologies that enhance environmental performance in the gold sector. In particular, CANMET is interested in the application of technologies outside the plant wall but inside the property fence.

Our approach to developing the environmental profile is based on a review of operating mines' regulatory licensing documents and published scientific literature. Regulatory documents issued to individual mines -- for example, an Ontario Ministry of the Environment Certificate of Approval -- reflect both the general environmental concerns with gold mining as well as site-specific factors. By reviewing regulatory documents for a group of mines, a comprehensive and documentable data base can be developed.

Information developed from the review of regulatory licensing documents is assessed and ranked in a hierarchy of potential environmental concerns. This hierarchy provides the basis for identifying and evaluating possible technological opportunities.

Environmental concerns associated with gold mining include many of the same issues that are typical of other metal mines. However, the gold sector has always included a large number of small operators and not been the subject of as much public scrutiny as other types of metal mining. Some environmental degradation from gold mining has resulted from the absence of suitable technology. For example, although metal mines in Canada have been regulated by the federal Metal Mining Liquid Effluent Regulations since 1977, gold mines are excluded since there was, in 1977, no demonstrated treatment process for removing cyanide from effluents.[1] Indeed, almost 15 years later there appears to be no technology which is consistently capable of reducing cyanide concentration in effluents below that known to be acutely toxic to fish.

The conventional way of determining technological needs is through consultations with the industry. Our review, however, has been carried out independently of the mine operators. This does not mean that we disagree with a consultative approach, nor does it mean that consultations should not take place. Rather, an evaluation based on the environmental issues identified by the regulatory authorities, in carrying out their licensing and approvals responsibilities, provides an alternative and effective means of identifying environmental concerns associated with gold mining. The conclusions of this study can then be compared with the industry's own assessment of its technological needs.

The information in this report could provide CANMET management with (a) a basis for discussions with the industry on environmental concerns, and (b) an evaluation of the need for new environmental technologies in the gold sector. We have limited our review to potential environmental problems associated with gold mining. Thus, the needs and opportunities for new technologies identified herein are specific to this sector. No attempt has been made to determine the extent to which these technologies are common to other sectors of the mining industry.

Section 1 of the report provides an overview of gold mining in the Timmins-Kirkland area as of 1989/90, based on information in published sources. A literature review of potential environmental problem areas in gold mining is also included in Section 1.

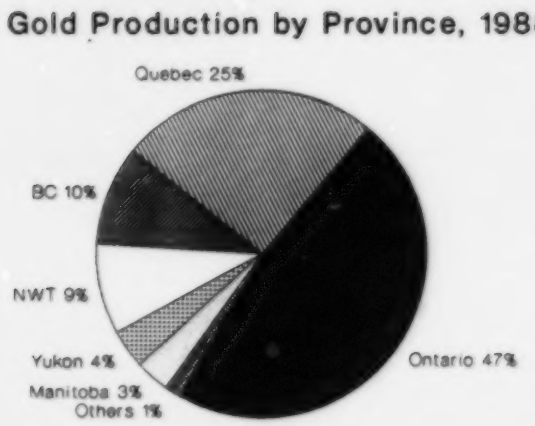
Section 2 presents the results of our review of licensing documents and includes our assessment of potential environmental concerns associated with gold mining, including an evaluation of their importance or severity.

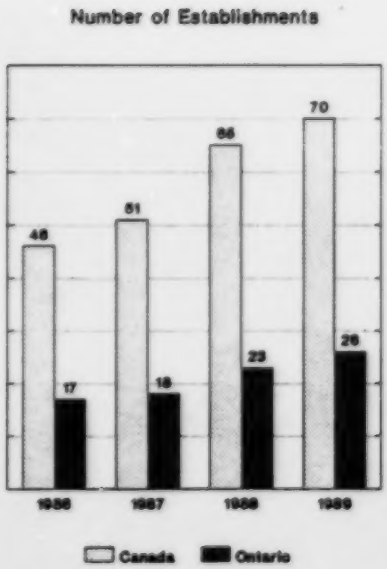
Finally, Section 3 provides our hierarchy of potential environmental problems, identifies the major areas of technological need, matches the environmental problems with possible solutions, and recommends specific research opportunities that lend themselves to initiatives that could be most appropriately pursued by CANMET.

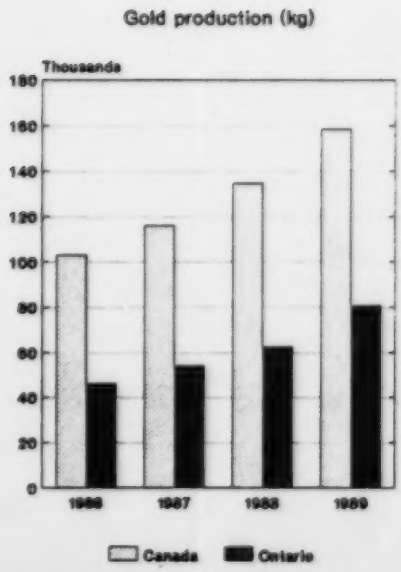
SECTION 1

BACKGROUND ON GOLD MINING

FIGURE 1.1 GOLD PRODUCTION IN CANADA







SECTION 1: BACKGROUND ON GOLD MINING

1.1 INTRODUCTION

The 134,813 kg of gold produced[2] in Canada in 1988 was worth $2.33 billion or about six percent of the country's annual mineral production. Among Canada's leading minerals, gold was third in value after nickel and copper. Gold mining takes place in all provinces and Territories except Alberta and Prince Edward Island, although production is concentrated in central and north-western Canada with Ontario contributing the largest share, 47%. Other provinces/territories which have a significant part of the national production are Quebec (25%), British Columbia (10%), and the Northwest Territories (9%), as shown in Figure 1.1 opposite.

Gold mining in Canada and Ontario has grown significantly in recent years, both in terms of the number of mines and the amount of gold produced. The number of establishments shown in Figure 1.1 may be slightly less than the number of individual mines since Statistics Canada does not always identify each separate mine when several nearby mines are owned by a single company.

Figure 1.1 shows that there are about 70 active primary gold mining/milling operations (establishments) in Canada, over one third (26) of which are located in the Canadian Shield area of Ontario.[2,3] (These are listed in Appendix 1 by location and their 1988 production.) The values given for gold production in Figure 1.1 for 1989 are estimates reported in the Canadian Mining Journal in March 1990. This list of operators may change significantly over a period of a few years as new developments come on-line and others close because of exhaustion of reserves, poor economics, etc.

The goal of this part of the report is to provide sufficient background on gold mining to facilitate an examination of the regulatory documents for the mines in the Timmins-Kirkland area. Thus, the following sections provide (a) specific information on the Timmins-Kirkland Lake area operations, (b) the results of our literature review of environmental concerns with gold mining, and (c) an overview of the regulatory environment as it applies to gold mines in Ontario.

1.2 GOLD MINES IN THE TIMMINS-KIRKLAND LAKE AREA

The Timmins-Kirkland Lake area has Ontario's largest number of gold mines and is second in gold production only to the Hemlo region. The area includes one producer who has been in operation for more than 80 years as well as some of Canada's newest mines. Thus, the number of mines, their production history and diversity makes the Timmins-Kirkland Lake area a good candidate for developing an environmental profile of the gold sector.

All the active gold mining operations in the Timmins-Kirkland Lake area at year-end 1990 are listed in Table 1.1 which shows their start-up date, whether the mine is underground or open pit, the daily milling capacity, mill process and the cash production costs per oz of gold. Our environmental profile and assessment is based on the 10 mine/mill complexes highlighted in Table 1.1. Falconbridge Gold Corporation's (formerly Kidd Creek Division) Owl Creek/Hoyle Pond mines were excluded because they ship ore to the nearby Timmins smelter where the gold is recovered by flotation.

Most of the Timmins-Kirkland Lake operations use cyanidation (using an alkaline cyanide solution, typically 0.1 - 1 kg cyanide per tonne of ore[4]) to dissolve the gold from the host rock. Most of the operations use conventional milling, although some recovery by heap leaching was begun in 1988. Gold in solution is recovered by either (a) the Merrill-Crowe process, (b) Carbon-in-Pulp (CIP) or (c) Carbon-in-Leach (CIL).

The Merrill-Crowe process uses zinc precipitation to recover gold from solution. In this process the solution must be clarified and de-aerated prior to the precipitation step. As a result, two separate waste streams are produced. The first is the washed, leached solids or tailings; the second is the barren leach solution. While most of the cyanide in the barren leach solution can be recycled, a certain portion is also bled off to disposal because of the unavoidable and unacceptable build-up of other metal cyanides in the recycle stream.

In the two carbon-based processes, gold cyanide is adsorbed from the leach slurry onto activated carbon which is separated from the slurry by screening. In the CIP process, leaching and adsorption take place sequentially in separate unit operations, whereas in the CIL process, leaching and adsorption take place simultaneously. Both carbon processes yield a single waste stream, the tailings slurry. The CIP and CIL processes have significantly lower capital installation and operating costs compared to the Merrill-Crowe process and have become popular in both newer and refurbished operations. There are however, limited opportunities for the recycling of cyanide solutions in these processes. Because the cyanide is associated with the tailings pulp, special clarification and/or treatment processes would be required to recover and recycle the cyanide.

TABLE 1.1: TIMMINS–KIRKLAND LAKE AREA GOLD MINES

Company	Mine/Mill Complex
American Barrick Resources Corp.	Holt–McDermott
Canamax Resources Inc.	Bell Creek
Eastmaque Gold Mine Inc.	Kirkland Lake
Deak Resources Corporation	Kerr Addison
Royal Oak Resources Ltd.	Pamour No. 1
Lac D'Amiante Du Québec Limitée (ASARCO)	Aquarius
Lac Minerals Ltd.	Macassa
Placer Dome Inc.	Dome
INCO Ltd.	McBean
St. Andrews Gold Fields Limited	Stock Twp.

* Converted from $Can. @ 0.86
** Evaluating potential for Open Pit.
*** Back in operation in 1990 as a custom Cu, Zn, Au mill, plus gold processing fro

Start	Mining Operations Type	Milling Operations Type	Capacity tonnes/day	1989 Cash Production Costs $US/oz
1988	U/G	Carbon–in–Leach	1,360	284
1987	U/G	Merrill–Crowe	400	299 *
1988	Tailings Reclaim	Flotation Only	1,827	not known
1938	U/G	Merrill – Crowe***	1620	not known
1936	Open Pit & U/G	Merrill–Crowe & Heap Leach	2,721	397 *
	U/G**	Flotation Only	273	On stand–by
1933	U/G		454	304 *
1989	Tailings Reclaim		680	159 *
1909	U/G and Open Pit	Carbon–in–Pulp	3,356	342
	Milling Only	Merrill–Crowe	635	On stand–by
1989	U/G	Carbon–in–Pulp	454	362 *

Kerr Mine.

1.3 LITERATURE REVIEW

Three CISTI (Canada Institute for Scientific and Technical Information) databases -- CISTIMON, AQUAREF and ELIAS -- were searched for literature references to environmental issues in the Canadian gold mining industry. The CANMET and Environment Canada libraries were also consulted for information that was not contained in the CISTI databases. In particular, information on effluent treatment practices was provided by Environment Canada, including one comprehensive status report on cyanide removal and recovery.

From our review of the references, we have drawn a number of conclusions on potential environmental problems associated with gold mining. These conclusions, summarized below, provided the basis and framework for our subsequent review of regulatory documents.

Generally, environmental concerns in the gold mining literature fall in two areas (a) water quality impairment as a result of contaminants in effluent discharges, and (b) tailings area stability after mine close-out. The overwhelming majority of the literature references deal with the issue of cyanide and its derivatives in effluent and methods for its removal or recovery. Other parameters, such as copper, iron, nickel, zinc, arsenic antimony and ammonia, are also identified as concerns, although to a much lesser extent. The references which identified problems with tailings disposal discuss dusting and erosion of tailings, instability of tailings dams, and potential contamination of ground water.

1.3.1 Geology and Mineralogy

The environmental impacts from mining may be strongly influenced by the geology and mineralogy of the ore -- for example, the presence of pyrite may result in acid mine drainage from waste rock piles or tailings areas. The occurrence of metals and sulphides in gold ores can have a significant influence on the amount of cyanide used in leaching. The overwhelming majority (about 85%) of the gold produced in Canada originates from the mining of ores consisting of native gold associated with quartz veins intruding in greenstone belts.[5] A small amount, less than four per cent, comes from mining alluvial or placer deposits and the remainder is a by-product of copper, nickel, zinc, silver or lead mining.

The literature identifies two mineralogy-related issues which may impact on the environment. First, gold ores may also contain sulphide minerals such as pyrite. Some mines use flotation processes for gold concentration indicating substantial concentrations of sulphide minerals and suggesting a potential concern with acid-generating wastes. Despite the presence of sulphides in some gold ores, gold mining in Canada is excluded from a national list of primary acid mine drainage sources prepared by Environment Canada.[6] Only one specific reference to acid generation from gold

mining wastes was found in our literature search, and it related to acid drainage from waste rock piles at a mine in Quebec[7]. Processing considerations contribute to maintaining residual alkalinity in gold tailings: the cyanidation extraction process is carried out under alkaline conditions and does not destroy excess buffering capacity in the ore, as is the case in acidic leaching operations.

Secondly, arsenic and antimony are sometimes associated with gold ores,[5] occurring as simple sulphides or metal arsenides or sulpharsenides such as arsenopyrite, and may be released in untreated effluents as a result of the milling process. Simple sulphides of arsenic and antimony dissolve in alkaline solution and therefore require specific and generally efficient treatment strategies when present in ores. Arsenopyrite is insoluble and disposed of largely unaltered with the tailings. The behaviour of arsenopyrite in tailings from such ores is not mentioned in the literature. When arsenic minerals occur in significant concentrations (> 1% As) in gold ores, they are usually roasted such as is the case in the Giant Yellowknife Mine in the Northwest Territories. In this case, the arsenic is converted to highly soluble arsenious oxide and again requires specific treatment strategies.

CONCLUSION: **The literature indicates that, unlike other sectors of the Canadian mining industry, acid drainage does not appear to be a concern with gold mining. Indeed, with the possible exception of ores containing high levels of arsenic and antimony, the mineralogy of gold ores does not appear to present any particularly difficult environmental problems.**

1.3.2 Tailings Management

Gold mining, like other metal mining and milling operations, results in large quantities of finely grained tailings which are deposited in natural depressions (which may contain lakes) or engineered impoundments. The capacity of tailings sites are typically 5 - 25 million tonnes and can cover areas up to 200 hectares.

Increasingly, tailings management is being seen primarily as a water management issue; tailings solids are relatively easy to dispose of, particularly if they are non-acid producing[8]. In contrast to effluent control and treatment, potential problems with tailings solids management appear to be associated with older or abandoned tailings areas. In particular, the literature identified three categories of possible environmental concerns: (a) erosion of tailings, (b) instability of tailings dams, and (c) potential ground water contamination.

The primary problem identified was that of dusting of fine tailings which may result in local air quality deterioration during certain weather conditions.[9,10] However, this may be primarily a question of aesthetics since no specific information is given on the

extent of the dusting or the associated hazards, if any. Many tailings areas have been revegetated which reduces this problem. No problems attributed to areas of *slimes* on tailings sites were found in the literature review.

Instability of tailings caused by water erosion is also of concern for older or abandoned tailings sites and can result in land slides, mud flows, and sedimentation of downstream water courses.[10] There was one dramatic tailings dam failure in 1990 where a large amount of tailings washed into the Montreal River near Elk Lake, Ontario. In this, and other similar occurrences, the public perception of the degree of environmental harm often greatly exceeds the actual damage caused. The most significant consequence is that the reputation of a particular operator, or the mining industry as a whole, is unnecessarily or unjustifiably effected in a negative way. Good design and operational practice can alleviate these types of stability problems in recent or new tailings areas.

Cyanide in ground water can be both persistent and mobile so that tailings areas need to be designed to limit seepage.[11] In addition, the rate of degradation and attenuation of cyanide in ground water is not known.[12] Field studies at two abandoned tailings areas showed high residual levels of cyanide in the old tailings, as well as some evidence of its migration in underlying soils.[12] Thus, ground water contamination by cyanide from tailings areas may be a potential problem, particularly for older or abandoned tailings areas. Currently, it is common practice to make tailings retainment structures impervious, although the degree of impermeability depends upon regulatory requirements, downstream water resources and the hydrogeological properties of the site. This trend to designing and building more impervious tailings containment basins should reduce or even prevent future problems with ground water contamination.

CONCLUSION: **The literature indicates that gold tailings management is primarily a water management issue. Current engineering practices appear to address satisfactorily most concerns relating to the stability of tailings, particulary since gold tailings are not acid generating. Older or abandoned tailings may, however, present some concerns for their stability and potential for ground and surface water contamination.**

1.3.3 Cyanide in Effluents

As noted, the literature contains more references to the occurrence, treatment and environmental consequences of cyanide releases from gold mines than any other issue.

CONCLUSION: **The literature indicates that the control of cyanide in effluents is the most important environmental issue relating to gold mining.**

Gold mines are exempt from Environment Canada's Metal Mining Liquid Effluent Regulations and Guidelines because, in 1977, there was no practical, effective effluent treatment technology for cyanide removal.[4] Provincial jurisdictions regulate total cyanide concentrations in gold mine effluents to 1 - 2 ppm (Ontario has the highest standard in Canada at 2 ppm) and weak acid-dissociable cyanide (or free cyanide) to 0.1 - 0.5 ppm.[13] These levels are significantly higher than the reported threshold of free cyanide concentration (0.03 - 0.15 ppm as HCN) for fish mortality.

CONCLUSION: **The literature indicates that current effluent guidelines for cyanide (total or free) may result in effluents which are acutely toxic to aquatic organisms.**

The chemistry of cyanide in gold effluent and natural waters is complex and the toxicity of the various species covers a broad concentration range. The literature identifies some deficiencies in the knowledge and analysis of cyanide and cyanide compounds in effluents.[12] In the past year there has been a significant effort to resolve these analytical difficulties.[14]

CONCLUSION: **The literature indicates that the chemistry and analytical measurement of cyanide and cyanide-related compounds in gold mill effluents may not be adequately understood.**

The literature reveals that up to about 1980, cyanide removal in the Canadian gold mining industry relied solely on natural degradation whereby cyanide concentrations in tailings ponds decrease through de-gassing of hydrogen cyanide, natural oxidation, precipitation, etc. However, this degradation process requires at least 9 to 10 months to achieve a major reduction in cyanide levels given the Canadian climate. Environment Canada's Wastewater Technology Centre has developed a model to predict the degree of cyanide degradation possible under specific field conditions.[15]

CONCLUSION: **The literature indicates that natural degradation is an effective process for cyanide removal from gold mill effluents. However, unless a waste management system has been designed for cyanide degradation, natural removal mechanisms may not provide sufficient treatment of gold mill effluents to protect aquatic life.**

At present, about one half of Canadian gold mining operations use some kind of chemical treatment process to oxidise cyanide to cyanate.[13] (This further indicates the limitation of natural degradation as a treatment option.) These chemical treatment processes are used as (a) a stand-alone facility, (b) a pre-treatment step to natural degradation, or (c) a polishing step after natural degradation.

The most commonly used processes are the INCO SO_2-air oxidation process (used at 10 Canadian operations) and the H_2O_2 oxidation process (used at 13 Canadian facilities.) Both processes use copper as a catalyst for the oxidation reaction and to precipitate iron cyanide. Both are capable of producing effluent with a cyanide concentration less than 1 ppm. These processes, however, have a number of deficiencies, namely:

(i) Residual cyanide concentrations in undiluted effluents from both chemical and natural degradation treatment processes may be toxic to fish.

(ii) The copper used as a catalyst in chemical treatment processes may persist in the treated effluents unless careful process control is maintained.

(iii) The fate and environmental impact of cyanide oxidation products -- cyanate and ammonia -- have not been fully evaluated. Cyanide in combination with ammonia is known to be more toxic to fish than comparable concentrations of the individual compounds.

CONCLUSION: **The literature indicates that chemical treatment processes for cyanide removal are effective in reducing cyanide in gold mill effluents. However, undiluted effluents may still be toxic to fish because of (a) residual cyanide levels or (b) the presence of toxic byproducts from treatment.**

Because of the relatively high cost of the cyanide reagent and increasing environmental awareness, there has been renewed interest in the application of technologies for cyanide recovery from mill effluents and reuse. Several processes have been developed at laboratory or pilot scale.[5,16,17,18,19] Most of these are based on acidification of the waste stream, volatilization of HCN, and re-neutralization of cyanide into caustic solution (AVR processes), although some use electrochemical purification of cyanide in solution.

A number of these recovery processes are suitable only for clarified barren solutions or tailings decants, while others are capable of treating both slurries and barren solutions. All appear to be capable of producing effluent with total cyanide concentrations below 1 ppm. (The electrochemical process results in no wastes. However, it is applicable to treating barren solutions only.) One obvious concern with all AVR-based processes is the potential hazard associated with the generation and handling of the extremely toxic gas hydrogen cyanide; this potential safety hazard may be the greatest barrier to implementing cyanide recovery at full scale.

Experience in Canada with cyanide recovery in full-scale process is limited to the use of AVR at one operation in Manitoba between 1935 and 1978 and at another in Saskatchewan from 1987 to 1989. A large-scale trial of a cyanide recovery process -- the CYANOSAVE™ process -- is scheduled to begin in the early part of 1991.[14]

CONCLUSION: **The literature indicates that cyanide recovery, as opposed to its destruction in effluent treatment processes, might offer the opportunity for (a) low cyanide in gold mill effluents, and (b) low residual cyanide concentrations in tailings solids.**

1.3.4 Other Parameters in Effluents

Environmental concerns for other contaminants in gold mill effluents appear to be over-shadowed by those for cyanide. Other parameters identified in the literature as potential concerns are heavy metals, arsenic, antimony and ammonia.[5,20] The heavy metals most commonly associated with gold effluents are iron, nickel, copper or zinc which usually exist in solution as metal-cyanide complexes. The cyanide treatment processes employed generally reduce the metal concentrations to acceptable levels. The single exception may be copper because of its use in the chemical treatment processes. As cyanide is oxidized, metal-cyanide complexes disassociate and the metals precipitate as hydroxides. (The prevailing pH of gold mining effluent is alkaline because cyanidation is carried out under alkaline conditions.) This is also true for less common metals such as mercury, molybdenum, or lead. No Canadian gold mine operates a treatment process exclusively for removal of any of the above metals.

Arsenic or antimony in effluents are not removed during such cyanide treatment processes although they may be oxidized to higher oxidation states. Thus, separate treatment processes are required for their control and removal. Four Canadian gold operators use arsenic and/or antimony treatment facilities (either alone or in conjunction with cyanide treatment) based on iron precipitation for the removal of these elements.[5] These treatment processes are well established and quite effective. An alternative process being proposed at one mine involves chemical pre-treatment of ores to remove arsenic and/or antimony prior to leaching.

Although no quantitative data on ammonia levels in gold mill effluents were found, the literature indicates that ammonia (originating either as a byproduct of cyanide degradation in leach liquors or barren solutions or from blasting agents used in mines) can occur in gold mill effluents at elevated concentrations.[5,13,21] Ammonia (as un-ionized NH_3) is acutely toxic to fish at relatively low concentrations -- as low as 0.3 mg/L.[5,22] Furthermore, at the alkaline pH's of most gold effluents, a significant portion of the ammonia would be present in the un-ionized form.

CONCLUSION: **The literature indicates that in general, contaminants other than cyanide occur at low levels in gold mill effluents with the possible exception of (a) copper which may persist at unacceptable levels in processes which use it as a catalyst in cyanide destruction, and (b) ammonia. The extent of the problem with ammonia in gold mill effluents has not yet been adequately investigated.**

1.3.5 Sludges

Effluent treatment processes used at gold mines produce sludges containing calcium, iron, other metals and, in some cases, arsenic and antimony. Settling ponds or clarifiers may be used for solid-liquid separation, and any recovered sludge is usually disposed of in the tailings area. The sludges produced are similar to those generated by other sectors of the mining industry, and may result in the release of metals under acidic leaching conditions.[23,24] However, given the high residual alkalinity in gold tailings and the relative small quantities of sludges, current treatment and management practice appears to be adequate.

CONCLUSION: **The literature indicates that the production, recovery and disposal of effluent treatment sludges do not appear to present any significant environmental concerns.**

1.3.6 Heap Leaching

Heap leaching is usually used for low grade ores which cannot be processed economically by conventional means. Canadian experience and interest in heap leaching has been limited because of the belief that Precambrian ores are not amenable to heap leaching[25] and also because of this country's harsh climate.[26]

There are currently three operations in Canada using heap leaching in full scale production which started during the late 1980s, namely:

- Hope Brook Gold Inc., Newfoundland
- Gordex Minerals Inc., Cape Spencer, New Brunswick
- Giant Yellowknife Mines Limited (Pamour), Timmins, Ontario.

In a heap leaching system, cyanide solution at a concentration of 0.25 - 0.5 g/L NaCN (similar to that used in conventional milling) is sprayed on to a large pile of ore at a rate of 2 - 30 L/m^2/day. The ore is pre-treated by crushing to a size of minus 7 - 12 mm, and sometimes, by agglomerating the fines to prevent them from clogging the heap. The leaching time varies from 15 to 75 days. Gold is recovered from the leachate by either a Merrill-Crowe, CIP or CIL process.[26,27,28,29,30]

The primary variations in heap designs involve either a reusable or dedicated pad. The reusable pad system, operated by Giant Yellowknife at Timmins, makes efficient use of limited space by leaching ore in three 90,000 tonne cells in a "batch" mode. Depleted ore is disposed of in the tailings area or used underground as mine backfill. The leach pad is reused.[28] The dedicated pad system, as used by Hope Brook Gold Inc., employs multiple lifts to make a pile ultimately containing a total of 800,000 tonnes of ore which is leached continuously.[27] When the entire heap has been leached, the waste ore is stabilized and revegetated. In either system, water flushing of the waste ores ensures that residual cyanide (and other contaminant concentrations) are reduced.[30]

The literature identifies two potential environmental concerns with heap leaching operations, both of which can be adequately addressed by standard engineering practices. First, the possibility of leach solution leakage to ground water is minimized by using a double liner system with inter-layer monitoring, or a downstream collection system (ponds or wells) with monitoring wells.[31] Secondly, downstream contamination from leachate collection pond overflows as a result of excessive precipitation is avoided by constructing collection ponds with sufficient capacity to accommodate specific run-off and storm events.[27]

CONCLUSION: **The literature indicates that potential environmental problems associated with heap leaching of gold ores in Canada are being addressed satisfactorily using current technology. However, longer operating history may be required to ensure there are no unanticipated long-term problems.**

1.3.7 Waste Rock

The management of waste rock in the mining industry is increasingly being seen as a potential environmental problem since it may (a) comprise a large quantity of material, (b) be a possible source of acid drainage, and (c) be the source of metal contamination in seepage and runoff.

Most gold is mined in Canada by underground methods and so the volume of waste rock produced may not be as great in relation to the total quantity of ore mined as in other mineral sectors.

In general, as discussed in Section 1.3.1, acid drainage is not considered a problem in the gold mining sector. Our literature review identified only one case where acid drainage from waste rock piles was a concern.[7]

The metals likely to be found in gold mill effluents (Section 1.3.4) primarily occur as a result of the cyanidation process, i.e., they are leached from the ore under harsh chemical conditions. Thus, leaching of metals from waste rock under normal climatic conditions might be expected to be considerably less.

CONCLUSION: **The literature indicates that there are few environmental problems associated with the management and disposal of waste rock in the Canadian gold industry. However, this conclusion is based on the absence of information references and could also indicate that the environmental implications of waste rock management and disposal have not been assessed.**

1.3.8 Decommissioning and Close Out

The public, regulatory authorities and financial communities are increasingly focusing their attention on the decommissioning and close out of mines once operations cease. There have been several recent instances where governments have required mining companies to post bonds prior to closure of a mining operation.[32] Much of the interest in decommissioning has focused on acid drainage, and as noted above, this does not appear to be a problem in the gold mining sector. Thus, concerns with the decommissioning and close out of gold mines may not be as great as those with base metal mines for example. However, several factors suggest that gold mines too will be subject to increasingly more rigorous close out requirements, for example:

- There are a large number of gold mines in Canada;
- The gold sector is particularly sensitive to economic cycles which make this sector particularly susceptible to mine closures;
- Gold ore may contain arsenic or other toxic elements;
- Mining generally involves land disruption; and
- The large number of old and abandoned mines, tailings areas, waste rock piles etc., ensures that this sector will not be excluded from public and regulatory attention.

There is little information in the literature relating to mine decommissioning or close out. One reference notes the potential for contamination of watercourses by leaching of cyanide from tailings over the long term.[12] Old and abandoned tailings are known to cause problems with leaching (at Deloro, for example) and dam failures (at Elk Lake in 1990, for example).

CONCLUSION: The literature identifies a number of environmental problems at old or abandoned gold mines as a result of incomplete close out. However, there does not appear to be any technical barriers to decommissioning gold mining properties although, in the absence of a technical framework, it may be difficult to judge what constitutes environmentally responsible decommissioning.

SECTION 2

REVIEW OF REGULATORY DOCUMENTS

SECTION 2: REVIEW OF REGULATORY DOCUMENTS

2.1 INTRODUCTION

This section of the report provides the results of our review and assessment of the regulatory documents issued to gold mines in the Timmins-Kirkland Lake area. The results from the review are a series of conclusions on the environmental impact of various aspects of gold mining. In addition, we have included a brief overview of the regulations which directly affect gold mining in Ontario.

2.2 THE REGULATORY ENVIRONMENT

Prior to examining the regulatory documents issued to gold mines in the Timmins-Kirkland Lake area, we reviewed the regulatory environment in which the mines operate. This regulatory overview (a) identifies the relevant environmental acts and regulations, and (b) provides the necessary background for our review of mine licences, certificates of approval and other regulatory documents.

Gold mines in Ontario are primarily regulated by the provincial government. Two ministries are responsible: the Ministry of the Environment (MOE) and the Ministry of Northern Development and Mines. Most of the operational controls at gold mines relating to the environment are issued by the MOE.

2.2.1 Ontario Ministry of the Environment

The Ministry of the Environment issues water taking permits, approves sewage treatment works (including tailings ponds and effluent treatment), regulates water and air emissions, and licences waste management operations. The following is a brief description of the areas regulated by MOE in carrying out their responsibilities for gold mines in Ontario.

Water taking permits

Section 61 of the Ontario Water Resources Act requires that approval be obtained to establish a waterworks capable of supplying more than 50,000 litres per day from a public watercourse. Like all large users of fresh water, gold mine operators must obtain a Certificate of Approval to take water.

Tailings area, effluent treatment works and final effluent quality

Section 24 of the Ontario Water Resources Act gives the MOE the responsibility for approving the design, construction and operation of sewage works. Sewage works include the tailings area, holding ponds, treatment plant and final discharge to a receiving watercourse. The approval granted under Section 24 of the OWRA is the single most important environmental approval granted gold mines in Ontario.
The Certificate of Approval issued to the mine operator includes a sampling schedule

and numerical limits for contaminants in effluents released to surface watercourses. The allowable concentration of final effluent parameters are set on a case-by-case basis as outlined in the MOE's Blue Book "Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment". Specifically, the procedure followed by MOE in setting effluent limits for gold mine effluents is described in Policy 3 of the Blue Book. This policy requires the Certificate of Approval issued to a mine to incorporate the most stringent of the following:

- The assimilative capability of the receiving surface watercourse.
  The characteristics of a receiving water body are considered in setting specific effluent concentrations at a specific property. An allowance for dilution in a mixing zone is permitted as long as this is not a substitution for treatment, the size of the mixing zone is minimized and acutely lethal concentrations of contaminants do not occur. Although some lowering of the receiving water quality is permitted, in no case is a violation of Provincial Water Quality Objectives (PWQO) allowed. The PWQO are given in Table 2.1 for the contaminants most likely to be present in gold mine effluents.

TABLE 2.1 ONTARIO PWQO FOR SELECTED PARAMETERS

Parameter	Concentration
Copper	5 µg/L
Lead	5 - 25 µg/L
Zinc	30 µg/L
Nickel	25 µg/L
Iron	300 µg/L
Arsenic	100 µg/L
Cyanide	5 µg/L
Ammonia	20 µg/L

- Provincial guidelines for effluents from mining operations.
  These guidelines set numerical concentration limits in mine effluents for a number of contaminants for all mining operations in the province. The limits, summarized in Table 2.2, are given in MOE's publication "Guidelines for Environmental Control in the Ontario Mineral Industry".

- The Federal Metal Mining Liquid Effluent Regulations.
  Under a Canada-Ontario agreement, the Province of Ontario has agreed to establish and enforce effluent requirements as least as stringent as the federal baseline regulations. The federal MMLER are summarized in Table 2.4 and, as discussed above, do not currently apply to gold mines using a cyanidation process.

TABLE 2.2: ONTARIO EFFLUENT GUIDELINES

Contaminant	Maximum allowable concentration
BOD5	15 mg/L
Total suspended solids	15 mg/L
Oil and grease	15 mg/L
pH	5.5 - 10.6
Sum metals (excl. Ca,Mg,K and Na)	1 mg/L
Sum Cu,Pb,Zn and Ni	1 mg/L
Cadmium and mercury	≤ background
NH_3-N	10 mg/L
Phosphorus	1 mg/L
Arsenic	0.5 mg/L
Total Cyanide (as HCN)	2 mg/L
Phenols	0.02 mg/L

A Section 23 approval under the OWRA is also required by a mine to operate a domestic sewage plant or potable water treatment plant.

MISA Monitoring Regulation Requirements

MISA is a province-wide program aimed at reducing the levels of pollution in effluents being discharged to the province's watercourses. The first phase of the program, the MISA Monitoring Regulation, was promulgated in 1990. All operating gold mines are required to sample effluents discharged to public watercourses. The purpose of the regulation is to develop a data base on the parameters in effluents which will be subject to control in a future Limits Regulation. The Limits Regulation will set allowable levels of specified parameters based upon the best available technology that is economically achievable (BATEA) and site-specific circumstances. Presumably, in the future, the MISA limits will be incorporated in operating Certificates of Approval.

Supporting documentation for the MISA monitoring regulation[33] notes that:

> "parameters that will or may be carried over to become part of a future limits regulation based on BATEA are sampled on a thrice weekly basis. Parameters sampled on a monthly basis may be carried over to become part of the future limits regulation. All other parameters are sampled on a quarterly basis to ensure that any seasonal changes in the effluents that may occur will be documented."

Based upon the sampling frequency, a hierarchy of importance for contaminants in gold mill effluents can be established, as shown in Table 2.3 below. Parameters of primary concern must be sampled three times a week; parameters of secondary concern are sampled three times weekly at large operations (greater than 1000 tonnes/day) and monthly at smaller operations; parameters of tertiary concern are sampled monthly at all operations. Finally, all parameters not on the list below are present at too low a concentration to be of concern or are being monitored quarterly for audit purposes as part of a broad Province-wide program.

TABLE 2.3: RANKING OF EFFLUENT PARAMETERS

Parameters of primary concern:
Total cyanide, Free cyanide, pH, Ammonia and ammonium, Total suspended solids, Oil and grease.

Parameters of secondary concern:
Copper, Lead, Nickel, Zinc and Arsenic.

Parameters of tertiary concern:
Chemical oxygen demand, Total Kjeldahl nitrogen, Nitrate and nitrite, Total phosphorous, Cadmium, Cobalt, Phenolics, Cyanates, Total dissolved solids, Iron and Thiocyanates.

CONCLUSION: **Based on the sampling frequency required by the MISA regulation, the contaminants of most concern in gold mine effluents are cyanide, pH, ammonia , suspended solids and oil and grease. The metals copper, lead, nickel, lead, zinc and arsenic appear to be of lesser concern.**

Air emissions

Regulation 308 of the Environmental Protection Act sets the maximum allowable concentration of airborne contaminants from stationary points of emission. The controlled contaminants and their maximum allowable half-hourly concentration at a point of impingement are specified in the regulation. The regulation also specifies how contaminant concentrations at a point of impingement are to be calculated from the known emission rate.

Regulation 308 also applies to industrial power plants or steam plants. Gold mines, in common with other industrial operators, must obtain a Certificate of Approval to operate such plants. The certificate limits visible emissions, sulphur dioxide, nitrogen oxides, etc.

Waste management and disposal

Solid waste management, which excludes tailings, is regulated under MOE's Regulation 309. This regulation (a) requires generators of hazardous wastes to be registered with MOE, (b) establishes waste manifest procedures, (c) registers PCB storage facilities, and (d) approves waste disposal facilities other than tailings areas. Gold mines, in common with all waste generators in the Province, are required to evaluate their wastes and register with the MOE if any of their wastes are listed on the various schedules in Regulation 309.

In the past, mine operators have used their tailings area for waste disposal. Current policy at MOE is to discourage this practice and keep solid wastes separate from tailings.

2.2.2 Ontario Ministry of Northern Development and Mines

The current Mining Act is concerned primarily with the land acquisition process and many of the approvals related to mining in Ontario are the responsibility of other ministries. The Ministry of Northern Development and Mines is not formally involved in these approvals, although its staff perform an advisory function to other ministries. The new Mining Act (Bill 71,1987) changes this considerably by involving the Ministry of Northern Development and Mines directly in the approvals process. The most significant changes from an environmental viewpoint are the decommissioning and close-out provisions of the new act.

Whereas mining companies in Ontario were formerly required to vegetate tailings areas prior to closing a mining operation in the province, the new act requires them to develop and obtain approval for a detailed closure plan before bringing a property into production. The closure plan covers all aspects of the operation, not just tailings, and requires the operator to allocate sufficient capital to cover the costs of implementing the plan. Abandonment of a property, failure to fully implement the plan and other examples of non-compliance expose the operator to fines of up to $30,000 a day and

liens against the property, thereby prohibiting the transfer of property, plant and equipment, leases, licences, etc.

Regulations for Part IX of the Mining Amendment Act 1989 -- the 20-page section of the Act relating to closure, abandonment and rehabilitation -- are expected to be come into effect by mid-1991. The proposed regulations stipulate what subjects are to be addressed in a closure plan, including measures to rehabilitate:

- Storage areas for tailings, ore, concentrate, rock, overburden and waste materials;
- Structures and facilities;
- Infrastructure;
- Mine openings to surface;
- Waste treatment systems;
- Storage of petroleum products, chemicals, and hazardous and toxic materials; and
- Dams and drainage control structures.

In addition, a closure plan must also address long-term and institutional issues such as the expected future uses of the land; a rehabilitation timetable; the nature, frequency and duration of monitoring; and contingency plans. Finally, the operator must identify the estimated capital and operating costs for rehabilitation, develop an expenditure schedule, and allocate the financial resources required to implement the plan.

CONCLUSION: **The new Mining Act in Ontario requires all mine operators to carry out extensive and detailed planning for decommissioning the entire mining operation as part of the regulatory approvals process prior to commencing operations. Existing mine operators are also required to develop detailed decommissioning plans.**

2.2.3 Environment Canada

The federal Department of the Environment regulates metal mines in Canada under the Fisheries Act. The Metal Mining Liquid Effluent Regulations were passed in 1977 and set limits for the parameters shown in Table 2.4 below, based upon the deleterious effect to fish, fish habitat and man's use of fish. The regulations apply as guidelines to operations which began prior to 1977 and have not been expanded since then. The MMLER are intended to be national baseline standards. Mines located in environmentally sensitive areas may be subject to stricter controls, and provincial or local governments may impose more stringent standards.

The numerical limits in the regulations are based on "best practicable technology" and do not apply to gold mines that use the cyanidation process since no demonstratable technology for cyanide removal from gold mill effluents existed in 1977.

Environment Canada officials indicate that regulation of gold mines is being considered and will probably await Ontario MOE's MISA limits regulation.

TABLE 2.4: FEDERAL EFFLUENT STANDARDS

SUBSTANCE	MAXIMUM MONTHLY ARITHMETIC MEAN	MAXIMUM COMPOSITE SAMPLE	MAXIMUM IN GRAB SAMPLE
Arsenic	0.5 mg/L	0.75 mg/L	1.0 mg/L
Copper	0.3	0.45	0.6
Lead	0.2	0.3	0.4
Nickel	0.5	0.75	1.0
Zinc	0.5	0.75	1.0
Total Suspended Matter	25.0	37.5	50.0
Radium-226	10.0 pCi/L	20.0 pCi/L	50.0 pCi/L
Minimum pH	6.0	5.5	5.0

2.3 REVIEW OF THE REGULATORY DOCUMENTS

This section of the report provides the results and conclusions of our review of the regulatory documents relating to the 10 identified gold mines in the Timmins-Kirkland Lake area.

The regulatory documents and other information reviewed are summarized in Table 2.5. This table identifies (a) the permits required by each mine, and (b) the specific documents we reviewed in our assessment. We did not judge it necessary to review all permits and certificates since there are obvious similarities and redundancies. For example, all mine operators require fresh water and are required to obtain a Section 61 permit. However, because this water is ultimately released as an industrial effluent, environmental factors are considered in the Section 24 approval.

As can be seen in Table 2.5, we reviewed all the Section 24 Certificates of Approval, most of the supporting documentation, several Mineral Information Surveys, and a representative selection of other permits and certificates. Also as noted in Section 2.2.1 above, the Certificate of Approval issued under Section 24 of the Ontario Water Resources Act is by far the most significant environmental approval granted gold mines in Ontario.

TABLE 2.5: REGULATORY DOCUMENTS REVIEWED

MINE/MILL	Holt–McDermott	Bell Creek	Kirkland Lake Tailings	Pamour No. 1	Aquarius	Macassa	Kerr	Dome	McBean	Stock Twp.
REGULATORY APPROVALS	Documents Reviewed									
OWRA Sec. 23: sewage/drinking water										
OWRA Sec. 24: effluent discharges	•	•	•	•	•	•	•	•	•	•
OWRA Sec. 61: water taking							•		○	
Regulation 308: air		na	•	na	na	na	na	na		
Regulation 309: waste disposal		na	na	na	na	na	•	na		○
Regulation 309: hazardous registration										
Regulation 309: PCB storage										
Other Information										
Mineral Industry Information Sheet			•					•	•	•
Supporting Documentation	•		•	•			•	•	•	•

KEY:

Document reviewed: •

Document not reviewed: ○

No applicable document: na

2.3.1 Approvals Granted Under Section 24 of OWRA

Our review of the Certificates of Approval issued by MOE under Section 23 of the OWRA focused particularly on the following areas of interest:

- Contaminant concentrations in effluents.
- Monitoring requirements: including both the contaminants to be monitored and the frequency of monitoring.
- Environmental impact assessments of receiving water bodies.
- Decommissioning and close-out plans.
- Other issues.

The results of our review and the conclusions we have drawn are given in the following sections.

Contaminant Concentrations in Effluents

Based on our review of 10 Certificates of Approval, the regulated parameters and their maximum permissable concentrations in effluents are generally similar at each operation. There were no unexpected parameters included, but the allowable concentrations for total cyanide and ammonia appear high considering the toxicity of their un-ionized forms (Section 1.3). The results of our review are shown in Table 2.6. It indicates that most of the regulated contaminants are those contained in the Ontario Mineral Industry Effluent Guidelines shown in Table 2.2.

Table 2.6 also shows that the more recent mining operations are subject to more stringent standards for cyanide and metals, as follows:

- the maximum allowable concentration of total cyanide is reduced from 2 mg/L to 1 mg/L;
- the maximum allowable sum of the concentrations of copper, nickel, lead and zinc is reduced from 1 mg/L to 0.8 - 0.5 mg/L;
- maximum allowable concentrations are now specified for copper, lead, nickel and zinc;
- narrower allowable range for pH.

Effluent discharges are restricted to certain periods of the year at some operations. Indeed, seasonal discharges are specified for the majority of the operations. This is consistent with the known degradation of cyanide and cyanide complexes during the warmer months of the year.

TABLE 2.6: EFFLUENT CONCENTRATION LIMITS IN CERTIFICATES OF APPROVAL

MINE/MILL	Holt–McDermott	Bell Creek	Kirkland Lake Tailings	Pamour No. 1	Aquarius	Macassa	Kerr	Dome	McBean	Stock Twp.
PARAMETER	Regulatory Limits (mg/L) for Effluent from MOE Certificates of Approval									
Total Cyanide	1	2	2	2	2		2		2	1
pH	6.5–8.5	5.5–10.6	5.5–10.6	5.5–10.6	6.5–10.5	5.5–10.6	5.5–10.6	5.5–10.6	5.5–10.6	5.5–9.5
Suspended Solids	15	15	15	15	15	15	15	15	15	15
Nickel	0.3				0.25					0.2
Copper	0.4				0.3					0.3
Lead	0.1				0.2					0.1
Zinc	0.1				0.25					0.1
Arsenic	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ammonia	10	10	10	10	10	10	10	10	10	10*
Phosphorous	1	1	1	1	1	1	1	1	1	1
BOD(5)	15	15	15	15	15				15	15
Oil/Grease	15	15		15	15				15	15
Cadmium	0.001				0.002				0.001	0.001
Mercury	0.001				0.001				0.001	0.001
Phenolics	0.02	0.02	0.02	0.02	0.02	0.02		0.02	0.02	0.02
Any metal**	1	1	1	1	1	1	1	1	1	1
Sum of Cu, Ni, Pb, Zn	0.8	1	1	1	1	1	1	1	1	0.5

* If pH > 8.5, regulated concentration is 5.

** Excluding Na, Mg, K, Ca.

CONCLUSION: **The Certificates of Approval do not identify any unusual or unanticipated contaminants in gold mill effluents; as expected, cyanide and metal levels are regulated at all operations. However, there is a move to requiring lower concentrations of these contaminants in effluents, indicating that the MOE's 1981 Ontario Mineral Industry Effluent Guidelines are not considered sufficiently stringent.**

Monitoring Requirements

The effluent monitoring requirements determined from the 10 MOE Certificates of Approval reviewed are shown in Table 2.7. The majority of the operations must sample effluent weekly for cyanide (total and weak acid dissociable), pH, suspended solids, metals, arsenic, ammonia, phosphorus, hardness and conductivity. The other parameters, which are primarily standard water quality concerns, are either sampled monthly or are required from a minority -- sometimes just one -- of the operators. Some possible exceptions are (a) mercury and cadmium at one mine are to be monitored weekly and (b) thiocyanate and cyanate are to be monitored weekly at two mines. Toxicity testing of the effluent is required monthly at the majority of the mines under review. Other monitoring requirements contained in the Certificates of Approval which are not shown in Table 2.7 are as follows:

- sulphides at one mine
- dissolved organic carbon at one mine
- open characterization, elements at one mine
- filtered copper at one mine

CONCLUSION: **The monitoring requirements specified in Certificates of Approval indicate that the parameters of concern in gold milling effluents are cyanide, pH, suspended solids, metals, arsenic, ammonia, phosphorous, hardness and conductivity. This is based on the fact that monitoring is required weekly. The requirement for regular toxicity testing indicates that effluents may be acutely toxic to fish even when they meet the regulated concentrations.**

Most of the Certificates of Approval require water quality in receiving water courses to be monitored. Generally, this consists of sampling the receiving water course up-stream and down-stream of the point of discharge of the effluent. The selection of the up-stream and down-stream sampling locations depends on the dilution ratio required and allows for a mixing zone. The parameters to be monitored are generally a reflection of

TABLE 2.7: EFFLUENT MONITORING REQUIREMENTS IN CERTIFICATES OF APPROVAL

MINE/MILL	Holt–McDermott	Bell Creek	Kirkland Lake Tailings	Pamour No. 1	Aquarius	Macassa	Kerr	Dome	McBean	Stock Twp.
PARAMETER	Sampling Requirements for Effluent from MOE Certificates of Approval									
Total Cyanide	W		W	W	W		W		W	W
WAD Cyanide	W		W	W	W		W		W	W
pH	W		W	W	W	W	W	W	W	W
Suspended Solids	W		W	W	W	W	W	W	W	W
Dissolved Solids			W			W	W			
Iron	W		W	W	W		W	W	W	W
Nickel	W		W	W	W	W	W	W	W	W
Copper	W		W	W	W	W	W	W	W	W
Lead	W		W	W	W	W	W	W	W	W
Zinc	W		W	W	W	W	W	W	W	W
Arsenic	W		W	W	W	W	W	W	W	W
Ammonia			W		W	W	W		W	W
Nitrate					W				W	
Phosphorous			W		W	W	W		W	
BOD(5)	M		W		M				M	W
Oil/Grease	M				M				M	W
Cadmium	M				M				M	W
Mercury	M				M				M	W
Phenolics			W		M	W			M	W
96 Hr LC50	M		M	M	M		Q		M	M
Alkalinity	W			W						W
Hardness			W			W	W		W	W
Conductivity	W		W	W		W	W			
Sulphate	W		W	W		W				
Thiocyanate	W			W						
Cyanate	W			W						
Na or Ca/Mg	W								W	
Bacteriological	M		W					Q		

KEY: W is Weekly, M is Monthly and Q is Quarterly.

those specified for the effluent entering the receiving water body. In most cases the sampling frequency is bi-weekly for down-stream sites and monthly for up-stream sites.

It is evident that the regulation of effluent discharges is becoming more directly related to the impact of effluents on receiving water quality. For example, operators must (a) carry out regular toxicity testing, (b) meet specified dilution requirements, (c) ensure that adequate equipment is in place for measuring the flow rate and volume of the effluents and in some cases of the receiving water body if it is a stream or river, and (d) assess the impact of the effluents on receiving water bodies.

In many of the Certificates, the requirements for meeting specific dilution ratios are variable and depend upon the ability to meet regulated contaminant concentrations in the effluent at any time. In these cases, if a contaminant concentration is exceeded in an effluent, greater dilution must be provided and more frequent toxicity testing is required. In one case, there is a requirement to carry out continuous toxicity testing if the specified dilution ratio cannot be met.

CONCLUSION: **Monitoring requirements in the Certificates of Approval indicate an increasing awareness of the potential impact of effluents on receiving water bodies. A more rigorous approach to dilution and the requirement for toxicity testing indicate increasing expectations that effluents should not be acutely toxic.**

Environmental Impact Assessments on Receiving Water Bodies

Many of the Certificates of Approval require the mine operator to carry out an environmental impact assessment of effluent discharges on the receiving water body. The terms of reference for an assessment must first be submitted to MOE staff for review. The study must include (a) a biological examination of fish and benthic organisms in the receiving water body, (b) an evaluation of changes in water chemistry and (c) a determination of the actual dilution of the effluent provided by the receiving water body.

We reviewed one study report which was submitted in response to such a condition. The study examined the environmental impact on the Porcupine and South Porcupine Rivers and concluded the overall effects of gold mining within the watersheds has been relatively minor on fish and other aquatic biota. The report suggests that the toxicity of metals such as copper may be less than is predicted from laboratory tests because of factors such as water hardness, buffering capacity or the formation of less toxic metal compounds by naturally-occurring organic materials.

CONCLUSION: **The requirement in Certificates of Approval for operators to determine the impact of effluent discharge on the receiving water body indicates that the environmental consequences of cyanide or metal releases are not known. Anticipated effects are based primarily upon laboratory studies and actual observed effects appear to be less than expected because of the assimilative capacity of natural water bodies.**

Decommissioning and Close-Out Plans

All the Certificates of Approval include a requirement on the operator to submit a detailed rehabilitation and revegetation plan for its tailings control system. The plan may be required either immediately of sometime prior to ceasing tailings disposal operations. The plan is required to outline the steps to be taken and is subject to review and approval by MOE. Several operators have included their plan with the supporting documentation for the Section 24 approval (see Section 2.3, below). The goal of the rehabilitation and revegetation plan is to minimize erosion and sedimentation in adjacent watercourses and avoid wind blown dust. The plan must be implemented as soon as practicable or within one or two years after tailings disposal operations cease.

CONCLUSION: **Current requirements in Certificates of Approval for decommissioning and close out apply to tailings areas only and do not appear to contain sufficient detail to allow a judgement of whether the plan is feasible or not. In addition, plans do not appear to address long term issues such as seepage, possible ground water contamination or land use.**

Other Issues

A number of other conditions included in some of the Certificates of Approval also indicate areas of environmental concern. These miscellaneous conditions are as follows:

- Frequent sampling and analysis of effluents for bacteriological contamination is required at two operations on account of sewage being co-disposed with tailings. At a third, it is required periodically if sewage sludge is used for soil amendment in tailings area revegetation.

- Daily mist sampling is required at the one operation employing a heap leaching process to monitor the potential carry-over of the leach solution spray.

- Ground water sampling is required at the one operation employing heap leaching. The purpose of the monitoring is to detect possible leakage of contaminants from the leaching pad rather than to demonstrate specific water quality objectives for ground water -- no concentration limits were specified for the parameters to be analyzed.

- One operation using chemical treatment for cyanide destruction and metals removal is required to quantify the generation of metal hydroxide sludge and to dispose of these with tailings.

- The most recently issued Certificate of Approval requires the operator to conduct an environmental audit which is to identify the potential optimization options in water and waste management practices and potential options to approach and achieve the Provincial Water Quality Objectives.

- Two operations are required to post bonds with the MOE of $250,000 each.

CONCLUSIONS:

The Certificates of Approval require analysis of bacteriological parameters in effluents where sewage is co-disposed with tailings.

One Certificate of Approval requires a need to monitor and quantify solution losses from heap leaching operations by wind-borne carry-over of spray and by seepage to ground water. The significance of these potential pathways for contaminant releases is not known.

The Certificates of Approval reveal no concerns for the long-term management or disposal of metal sludges produced by effluent treatment plants. Disposal of such sludges to the tailings area is an acceptable practice.

The most recent Certificate of Approval includes a requirement to determine the feasibility of gold mine effluents meeting Provincial Water Quality Objectives.

The Certificates of Approval indicate concerns for long term management of tailings and effluent treatment by requiring operators to post performance bonds.

2.3.2 Mineral Industries Information Sheets

The Mineral Industries Information Sheet (MIIS) is an extensive and detailed questionnaire which must be completed by a mine operator as part of the MOE's permitting activities. The survey contains 96 questions dealing with general information on the company, operating schedules and history as well as detailed technical data on geology and mineralogy, mining, milling and the tailings area.

Mineralogical information in an MIIS was of particular interest in our review. The MIIS gives details on the presence and abundance of the ore and gangue minerals, including the amounts of pyrite, pyrrhotite and arsenopyrite. Table 2.8 below shows the reported amounts of these sulphide minerals in three ore bodies as reported in the respective MIIS. The MIIS also reports the presence of calcite or other acid neutralizing minerals in the ores.

TABLE 2.8: SULPHIDE MINERALS IN ORE BODIES

MINE/MILL	PYRITE(%)	PYRRHOTITE(%)	ARSENOPYRITE(%)
Holt-McDermott	2-5	0	0
Dome	1-3	1-3	Trace
Kirkland Lake Tailings	1-2	0	0

CONCLUSION: Information in the Mineral Industries Information Sheets confirms the relatively small amounts of pyrite, pyrrhotite and arsenopyrite in gold ores. Acid drainage is not anticipated to be a problem from tailings or waste rock, especially given the presence of alkaline chemical residues from processing and the usual presence of small amounts of alkaline minerals like calcite.

2.3.3 Supporting Documentation for Section 24 Approvals

As shown in Table 2.5, Environment House reviewed documents filed by mine operators in support of their application to discharge an industrial effluent (Section 24, OWRA). The supporting documents[34 - 44] contain detailed technical information including geotechnical details on the sites as well as details on proposed dam and dike construction.

For the purposes of our review, we have segmented the information in the supporting documentation according to information on four principle areas of interest, namely:

- Tailings Management: including siting, design, operation and close out and decommissioning of the tailings area.
- Effluent Treatment: including laboratory testing, the proposed treatment system and predicted final effluent quality.
- Receiving Water Quality: based on the predicted effluent quality and the estimated dilution in the receiving watercourse.
- Decommissioning: including any close out or rehabilitation plans for tailings areas or treatment ponds, and frequency of sampling.

Table 2.9, following, summarizes the relevant information on each of these four areas for the individual operations reviewed. Based on the conclusions of our literature survey, we have identified deficiencies or problem areas which may be attributed to technical limitations. It should be remembered that Table 2.9 does not necessarily present a comprehensive review and assessment of the supporting documentation. Rather, it should be seen as a checklist where areas of potential environmental concern or technical limitation are identified. Our conclusions for each of the four areas are given below.

Tailings Management

CONCLUSION: **The supporting documentation indicates that tailings management consists of a solids containment area and one or two clearwater ponds. Solids containment areas are relative large because of the flat terrain which also may limit the size of the clearwater ponds. Dykes generally incorporate a clay or till core to limit seepage.**

Effluent Treatment

CONCLUSION: The supporting documentation reveals that mine operators can meet the Mineral Industry Effluent Guidelines using natural degradation alone or in combination with chemical treatment. Indeed, both chemical treatment and well designed clearwater ponds with long residence times and seasonal releases appear capable of outperforming the requirements of the Mineral Industry Effluent Guidelines for cyanide and metals. No mention is made with respect to performance for meeting ammonia levels or passing fish toxicity tests.

Receiving Water Quality

CONCLUSION: The supporting documentation reveals that meeting the Provincial Water Quality Objectives in a receiving water body is often difficult for gold mines. In fact, the PWQO can only be met in those cases where there is sufficient dilution by the receiving water body. (Policy 2 dischargers are not required to meet the PWQO because the receiving water quality has been previously impaired.)

Decommissioning

CONCLUSION: The supporting documentation provides decommissioning plans for tailings areas only. Most plans call for draining the tailings, contouring dams and vegetation. However, because the plans generally are very preliminary and conceptual in nature, it is difficult to determine if there are any technical barriers to implementation.

TABLE 2.9: SUMMARY OF SUPPORTING DOCUMENTATION FOR SECTION 24 APPROVALS

MINE/MILL	TAILINGS MANAGEMENT	EFFLUENT TREATMENT	RECEIVING WATER QUALITY	DECOMMISSIONING
Stock Twp. (1988)	60 ha tailings area designed for 850,000 tonnes. Sited in swampy area. Perimeter dikes incorporate a clay seepage barrier. Coarse material used as backfill. Sewage disposed to tailings. Small clearwater pond.	Treatment required for cyanide, metals and arsenic. Natural oxidation gave acceptable concentrations of copper, zinc and arsenic. Chemical treatment required for cyanide, iron and nickel. Testwork found an increase in copper following chemical treatment.	Provincial Water Quality Objectives met in receiving watercourse.	Preliminary plan only. Closed out tailings will have pond and dry areas. Vegetation will be used for stabilization. Downstream sides of dams will be riprapped and vegetated. Surface water will be diverted.
Bell Creek (1985)	25 hectare tailings area consisting of solids storage area and large clearwater pond. Dams incorporate till cores and overlie clay.	Treatment required for cyanide and metals. Natural degradation used. Recognise unknown factors in natural degradation. Effluent release July - December only.	Provincial Water Quality Objectives met well downstream in receiving watercourse.	Preliminary plan only. Acid drainage is not a problem. Tailings will be drained and contoured and natural vegetation allowed.
Holt-McDermott (1988)	Two years retention capacity in tailings area without effluent release. Two large clearwater ponds. Discharge schedule allows effluent release over three months following a 21 month holding period.	Treatment required for cyanide and metals. Natural degradation used. Engineered system gives better quality effluent than chemical treatment systems.	Initially could not meet Provincial Water Quality Objectives because receiving watercourses are small systems incapable of providing required dilution or assimilation.	Preliminary plan only. Tailings will be vegetated to limit erosion.
Dome (1983)	No. 6 Tailings area is a large tailings area with capacity for 30 years. Coarse material used as backfill. Two older tailings areas are used for mill effluent storage to allow natural degradation.	Natural degradation in tailings area. Predicted effluent quality; 15 ppm suspended solids, 1.5 ppm cyanide and pH 9.	This is a Policy 2 discharger: receiving waterbody is South Porcupine River. River water quality has been impaired by many decades of mining.	Extensive experience with tailings reclamation by revegetation is noted. Plans call for flattening steep tailings dam slopes and vegetating them. An emergency spillway will be designed to allow runoff.
Kirkland Lake Tailings (1986)	Tailing recovery and reprocessing project. Tailings being processed now fill up much of Kirkland Lake.	Effluent predicted to meet drinking water standards except for iron and sulphate.	This is a Policy 2 discharger. Effluent discharged to small remaining area of Kirkland Lake.	Quite detailed decommissioning and reclamation plan. Multiyear program involving (a) revegetation using municipal sludge as a soil amendment, (b) tree planting, and (c) annual maintenance.
Kerr (1990)	Two tailings areas - one for gold tailings and one for base metal tailings. Reduced water consumption through recycling.	Treatment required for cyanide, metals and arsenic. Natural degradation used.	This is a Policy 2 discharger: effluent is discharged to water body with poor water quality.	Preliminary plan only. Tailings will be vegetated to limit erosion.

2.3.4 Certificate of Approval under Regulation 308

Regulation 308 deals with industrial air emissions. We identified only one Certificate of Approval under Regulation 308 among the 10 operators in the Timmins-Kirkland Lake area. In addition, the Certificate of Approval appears to be largely a formality since it does not include any regulated emissions and does not include any requirement for monitoring.

CONCLUSION: **The absence of regulated emissions in Certificates of Approval and/or the limited requirements for such Certificates implies there are no substantial air related problems associated with gold mining.**

2.3.5 Permits to Manage Solid Wastes

Only two licensing documents relating to solid waste management were identified in our review. Both approvals related to the development or operation of a disposal site for non-hazardous solid wastes, and do not contain any considerations or requirements specific to gold mines. We did not review any of the hazardous waste registration records required under Regulation 309. However, based on our discussions with MOE staff, these requirements do not indicate any significant environmental problems or concerns.

CONCLUSION: **The absence of any unusual or noteworthy requirements indicates that the management and/or disposal of solid or hazardous wastes does not present any particular difficulties for gold mine operators.**

2.4 IDENTIFICATION OF ENVIRONMENTAL ISSUES

Our identification of potential environmental problems in gold mining is based on our review of (a) published literature on gold mining, and (b) relevant regulatory documents issued to gold producers in the Timmins-Kirkland Lake area. Although we believe our evaluation is applicable to the Canadian gold mining sector in general, because this assessment of the regulatory documents has been limited to 10 operators in the Timmins-Kirkland Lake area, the following identification of environmental issues may not include some site-specific environmental problems at other mining camps in Canada.

The following sections of the Environment House report consolidate the conclusions we drew from the review of the literature and regulatory documents outlined in previous sections. In general, the conclusions from the literature review (Section 1.3) agree with or compliment the conclusions from the regulatory documents review (Section 2.3). The conclusions are grouped into the major environmental areas such as geology, effluents, waste rock, etc. While this repeats the previous conclusions, we believe the presentation of both sets of conclusions together provides a useful summary of the earlier sections of our report.

The conclusions are shown side-by-side in the following pages -- the left hand column gives the literature conclusions and those from the review of regulatory documents are shown on the right. This presentation allows the two sets of conclusions to be contrasted and facilitates the identification of the potential environmental problem areas.

Together these conclusions provide the basis for our ranking of environmental issues in the gold mining sector. In turn, this ranking allows us to identify significant technological deficiencies and opportunities for research to correct them.

ENVIRONMENTAL CONCLUSIONS FROM A REVIEW OF.....	
..... LITERATURE	..... REGULATORY DOCUMENTS
2.4.1 Geology The literature indicates that unlike other sectors of the Canadian mining industry, acid mine drainage does not appear to be a concern with gold mining. Indeed, with the possible exception of arsenic and antimony, the mineralogy of gold ores appear not to present any problems.	Information in the Mineral Industries Information Sheets confirms the relatively small amounts of pyrite, pyrrhotite and arsenopyrite in gold ores. Thus, acid drainage is not anticipated to be a problem.
2.4.2 Tailings The literature indicates that gold tailings management is primarily a water management issue. Current engineering practices appear to address satisfactorily most concerns relating to the stability of tailings, particulary since gold tailings are not acid generating. Older or abandoned tailings may, however, present some concerns for their stability and potential for ground water contamination.	The supporting documentation indicates that tailings management operations at gold mines are generally routine. Tailings facilities consist of a solids containment area and one or two clearwater ponds. Solids containment areas are relative large because of the flat terrain which also may limit the size of the clearwater ponds. Dykes generally incorporate a clay or till core to limit seepage.
2.4.3 Effluents The literature indicates that the control of cyanide in gold mine effluents is the most important environmental issue relating to gold mining. The literature indicates that cyanide recovery, as opposed to its destruction in effluent treatment processes, might offer the opportunity for (a) low cyanide in gold mill effluents, and (b) low residual cyanide concentrations in tailings solids.	Certificates of Approval do not identify any unusual or unanticipated contaminants in gold mill effluents; as expected, cyanide and metal levels are regulated at all operations. However, the move to requiring lower levels of these contaminants indicates that the levels in the MOE's 1981 Ontario Mineral Industry Effluent Guidelines are not considered sufficiently stringent.

LITERATURE

The literature indicates that in general, contaminants other than cyanide occur at low levels in gold mill effluents with the possible exception of (a) copper which may persist at unacceptable levels in processes which use it as a catalyst in cyanide destruction, and (b) ammonia. The extent of the problem with ammonia in gold mill effluents has not been investigated.

The literature indicates that natural degradation is an effective process for cyanide removal from gold mill effluents. However, unless a waste management system has been designed for cyanide degradation, natural removal mechanisms may not provide sufficient treatment of gold mill effluents to protect aquatic life.

The literature indicates that chemical treatment processes for cyanide removal are effective in reducing cyanide in gold mill effluents. However, undiluted effluents may still be toxic to fish because of (a) residual cyanide levels, or (b) the presence of toxic byproducts from treatment.

REGULATORY DOCUMENTS

Based on the sampling frequency required by the MISA regulation, the contaminants of most concern in gold mine effluents are cyanide, pH, ammonia, suspended solids and oil and grease. The metals copper, lead, nickel, lead, zinc and arsenic appear to be of lesser concern.

Monitoring requirements in Certificates of Approval indicate that the parameters of concern in gold milling effluents are cyanide, pH, suspended solids, metals, arsenic, ammonia, phosphorous, hardness and conductivity. The requirement for regular toxicity testing indicates that effluents may be acutely toxic to fish even when they meet the regulated concentrations.

The Certificates of Approval indicate bacteriological parameters in effluents are of concern only when sewage is disposed with tailings.

The supporting documentation reveals that mine operators can meet the Mineral Industry Effluent Guidelines using natural degradation alone or in combination with chemical treatment. Indeed, both chemical treatment and well designed clearwater ponds with long residence times and seasonal releases appear capable of outperforming the requirements of the Mineral Industry Effluent Guidelines for cyanide and metals.

..... LITERATURE

..... REGULATORY DOCUMENTS

2.4.4 Receiving Water Quality

The literature indicates that current effluent guidelines for cyanide (total or free) may result in effluents which are acutely toxic to aquatic organisms.

The supporting documentation reveals that meeting the Provincial Water Quality Objectives in a receiving water body is often difficult for gold mines. In fact, the PWQO can only be met in those cases where there is sufficient dilution by the receiving water body. (Policy 2 dischargers are not required to meet the PWQO because the receiving water quality has been previously impaired.)

Monitoring requirements in the Certificates of Approval indicate an increasing awareness of the potential impact of effluents on receiving water bodies. A more rigorous approach to dilution and the requirement for toxicity testing indicate increasing expectations that effluents should not be acutely toxic.

The requirement for an operator to determine the impact of effluent discharge on the receiving water body indicates that the environmental consequences of cyanide or metal releases are not known. Anticipated effects are based primarily upon laboratory studies and actual observed effects appear to be less than expected.

The most recent Certificate of Approval includes a requirement to determine the feasibility of gold mine effluents meeting Provincial Water Quality Objectives.

The literature indicates that the chemistry and analytical measurement of cyanide and cyanide-related compounds in gold mill effluents may not be adequately understood.

LITERATURE	REGULATORY DOCUMENTS
2.4.5 Heap Leaching The literature indicates that potential environmental problems associated with heap leaching of gold ores in Canada are being addressed satisfactorily using current technology. However, longer operating history may be required to ensure there are no unanticipated long-term problems.	One Certificate of Approval requires a need to monitor and quantify solution losses from heap leaching operations by wind-borne carry-over of spray and by seepage to ground water. The significance of these potential pathways for contaminant releases is not known.
2.4.6 Sludges The literature indicates that the production, recovery and disposal of effluent treatment sludges do not appear to present any significant environmental concerns.	The Certificates of Approval reveal no concerns for the long-term management or disposal of metal sludges produced by effluent treatment plants. Disposal of such sludges to the tailings area is an acceptable practice.
2.4.7 Waste Rock The literature indicates that there are few environmental problems associated with the management and disposal of waste rock in the Canadian gold industry. However, this conclusion is based on the absence of information references and could also indicate that the environmental implications of waste rock management and disposal have not been assessed.	Information in the Mineral Industries Information Sheets confirms the relatively small amounts of pyrite, pyrrhotite and arsenopyrite in gold ores. Thus, acid drainage is not anticipated to be a problem.

LITERATURE

2.4.8 Decommissioning

The literature identifies a number of environmental problems at old or abandoned gold mines. However, there does not appear to be any technical barriers to the decommissioning and close out of gold mines although, in the absence of a technical framework, it may be difficult to judge what constitutes environmentally responsible decommissioning.

REGULATORY DOCUMENTS

Certificates of Approval show that current requirements for decommissioning and close out apply to tailings areas only and do not appear to contain sufficient detail to allow a judgement of whether the plan is feasible or not. In addition, plans do not appear to address long term issues such as seepage, possible ground water contamination or land use.

The supporting documentation provides decommissioning plans for tailings areas only. Most plans call for draining the tailings, contouring dams and vegetation. However, because the plans generally are very preliminary and conceptual in nature, it is difficult to determine if there are any technical barriers to implementation.

The Certificates of Approval indicate concerns for the long term management of tailings management and effluent treatment and require operators to post performance bonds.

The new Mining Act in Ontario requires all mine operators to carry out extensive and detailed planning for decommissioning the entire mine as part of the regulatory approvals process prior to commencing operations. Existing mine operators are also required to develop detailed plans.

..... LITERATURE	..... REGULATORY DOCUMENTS
2.4.9 Air Emissions (No information on air emissions was available in the literature.)	The absence of regulated emissions in Certificates of Approval and/or the limited requirements for such Certificates implies there are no substantial air related problems associated with gold mining.
2.4.10 Solid Wastes (No information on air emissions was available in the literature.)	The absence of any unusual or noteworthy requirements indicates that the management and/or disposal of solid or hazardous wastes does not present any particular difficulties for gold mine operators.

SECTION 3

ISSUES AND TECHNOLOGY-BASED OPPORTUNITIES

SECTION 3: ISSUES AND TECHNOLOGY-BASED OPPORTUNITIES

3.1 INTRODUCTION

The environmental issues associated with gold mining are reviewed and ranked in this section. The relative importance of each environmental issue is based upon our review of the literature and regulatory documents issued to gold mines in the Timmins-Kirkland Lake area, as summarized in the conclusions in Section 2. In addition, this section of the report (a) elaborates on the most serious environmental problems, (b) identifies technological needs to address and solve the problems, and (c) recommends opportunities for CANMET's involvement in developing effective and timely solutions. In recommending possible areas for CANMET's involvement, Environment House has considered the significance of work being carried out by other government agencies and the private sector. In particular, we have attempted to focus on the technological needs which are national in scope and are best suited to CANMET's significant experience with mining, processing and environmental technologies.

3.2 RANKING OF ENVIRONMENTAL ISSUES

The following section gives our ranking of the environmental issues associated with gold mining in terms of their environmental significance, according to four criteria. Each of the criteria was assigned three levels of significance: major, moderate and minor. Issues of major significance were assigned a value of 3, moderate a value of 2 and minor a value of 1.

The four criteria used in our evaluation are as follows:

- Understanding of impact: Are there major knowledge gaps in understanding the causes and consequences of a particular environmental issue (score = 3) or are they well known (score = 1)?

- Severity of impact: Are the environmental consequences potentially significant (score = 3) or are they minor or difficult to quantify (score = 1)?

- Scope of impact: Does a particular environmental problem have the potential to impact on a wide area (score = 3) or is it contained within the mine property (score = 1)?

- Duration of impact: Do the environmental consequences persist beyond the operating life of the mine (score = 3) or are they only short term (score =1)?

Individual scores for the four impact criteria were summed to give the total. A score of eight or more indicates a potential serious problem relative to the environmental issues considered in our assessment. Conversely, a minimum score of 4 suggests that the environmental issue is minor or inconsequential. Once the total scores were developed for all the environmental issues, they were ranked from high score (worst) to low (best).

The results of the ranking are given in Table 3.1, which shows the total score assigned to each of the environmental issues as well as the individual scores for the four criteria. The table is arranged from high total score to low so that the most serious environmental concerns are listed first. The following sections provide some insight into our identification of the environmental issues and the reasons for the ranking shown in Table 3.1. We have provided a brief description of the concerns which led to our assigning relatively high scores to each of the environmental areas in Table 2.10. Specifically, we have attempted to identify why a particular area is of concern and to quantify the seriousness of the impacts.

TABLE 3.1: RANKING OF ENVIRONMENTAL ISSUES

Ranking Criteria

Environmental Issue	DURATION	SCOPE	SEVERITY	UNDERSTANDING	TOTAL SCORE
DECOMMISSIONING					
Entire Mine Property	3	2	3	3	11
RECEIVING WATER BODY					
Water Quality	2	2	3	3	10
EFFLUENTS					
Cyanide	2	3	2	2	9
Ammonia	3	3	2	2	10
Metals	2	2	2	3	9
Acute Toxoicity	2	3	2	2	9
TAILINGS					
Stability	2	1	2	3	8
Ground Water Contamination	2	1	2	3	8
GEOLOGY					
Acid Mine Drainage	1	1	2	3	7
Arsenic	1	1	2	3	7
Metals	2	1	2	3	8
WASTE ROCK					
Acid Drainage	1	1	2	3	7
Overall Management	2	1	1	3	7
SOLID WASTES					
Industrial	1	1	2	3	7
Hazardous	1	1	1	2	5
SLUDGES					
Sludge Management	1	1	1	3	6
HEAP LEACHING					
Seepage	1	1	1	2	5
Mist	1	2	1	1	5
AIR EMISSIONS					
Air Quality	1	1	1	2	5

3.2.1 Decommissioning

An improperly or incompletely decommissioned mine site may cause serious environmental impacts which extend well beyond the property boundary. At present, decommissioning efforts at gold mine sites appear to be limited to safety issues related to mine openings and stability issues related to the tailings area. There is little evidence that decommissioning of the entire mine property -- tailings area, sludge ponds, waste rock piles, mill buildings, etc. -- has been adequately addressed. In addition, rehabilitation plans for tailings areas focus on short-term concerns such as dusting or sediment transport, and do not deal with longer term concerns such as maintenance of vegetative covers, land use or possible leaching of contaminants. The absence of an acid drainage problem obviously reduces the environmental concerns associated with closed out gold mines. However, the long-term environmental consequences of closed out sites have not been characterized in sufficient detail to determine whether or not there are other potential long-term repercussions.

Although the regulatory framework is being developed in some jurisdictions, we did not identify any evidence that a technical framework exists which is capable of providing a mine operator with the tools either (a) to determine what constitutes satisfactory decommissioning or (b) to implement decommissioning works which address long-term environmental concerns. The new Mining Act in Ontario increases the need for such a technical framework.

3.2.2 Receiving Water Bodies

In the past, a mine operator's responsibility for liquid discharges was primarily focused on meeting the effluent standards. As long as these were met, the assimilative ability of the receiving water body was assumed to provide adequate protection of downstream water bodies. Recently, this has been changing with regulatory authorities paying closer attention to the loadings of contaminants and the dilution afforded by the receiving water body. Despite this move to protecting downstream water quality, there is little information on the actual impacts of gold mining on receiving water bodies. In addition, there is little information on what organisms or parameters should be monitored to determine the effects of gold mining and ensure downstream water quality is adequately protected.

We have identified receiving water quality as a serious potential concern because (a) mine effluents may impact a large area beyond the mine property, (b) a variety of organisms may be affected, and (c) there is little documented information on effects monitoring. While it is recognised that no industrial activity can result in a pristine environment, it is also becoming clear that a gold mine operator will have to demonstrate that his effluents do not cause any significant deterioration of downstream water bodies. The technical guidelines and/or methodology for effects monitoring currently do not appear to be available to a gold mine operator.

3.2.3 Effluents

It appears that gold mine effluents routinely are acutely toxic to fish because of the presence of cyanide, ammonia and, perhaps, metals. Cyanide and ammonia are of particular concern because there does not appear to be any technology capable of reducing their concentration in mine effluents to non-toxic levels. In addition, the synergetic effects of cyanide and ammonia have not been considered in setting effluent standards. The occurrence of metals in mine effluents even at low levels is of some concern because, unlike cyanide and ammonia, they may persist in the environment for a long time after they are discharged. A very significant improvement in treatment technology for cyanide, ammonia and metals is required so that undiluted effluents are capable of passing the acute toxicity test. Thus, the feasibility of alternative means of achieving non-toxic effluents from gold mines is worth investigating. These alternatives might include process modifications leading to cyanide recovery or a "zero effluent" mill.

3.2.4 Tailings

Stability concerns -- for example, dusting or minor erosion -- and possible ground water contamination were identified as the environmental issues associated with current gold tailings management practice. All of these may have long-term impacts, although the anticipated environmental consequences are relatively small and localized. Current tailings areas and dams are being designed and built to higher engineering standards than was the case in the past. However, we did not identify any substantive studies or field investigations that quantified the environmental effects of current tailings management practices other than the engineering and geotechnical aspects.

There appears to be a need to determine the significance of minor erosion and possible seepage from tailings areas. Issues to be addressed include the persistence of cyanide or ammonia in pore water and their degradation in ground water, should they migrate from the tailings.

3.2.5 Geology

The environmental implications of geology result from the quantity of chemicals used in the mill, leaching of metals from waste rock or tailings, etc. The duration and scope of these environmental consequences may be quite severe, as is obvious at mines where there is acid drainage. However, since gold ores do not contain an excess of acid generating minerals, and there is little evidence of large amounts of metals such as arsenic, mercury or antimony, the significance of any environmental effect appears to be relatively minor.

There is no evidence that the environmental consequences of geology have been assessed. Such an evaluation may be justified, although it is of low priority.

3.2.6 Waste Rock

Waste rock may represent an environmental concern because of its potential for acid drainage and because of the long-term stability -- both chemical and physical -- of waste rock piles. Both of these issues are of minor concern for gold mines, however. Most mining is carried out underground and, thus, does not result in large quantities of waste rock. Also, gold ores are not acid generating in most cases. Nevertheless, the long term implications of improper management of waste rock may justify an assessment to confirm that it is not an environmental problem.

3.2.7 Solid Wastes

Solid waste management is a relatively minor environmental concern at gold mines. Solid wastes include industrial refuse and hazardous wastes but exclude tailings and waste rock. While non-hazardous industrial wastes were formerly disposed of in the tailings area, companies are tending to construct specific landfill sites. These landfill sites may have long-term implications, although any concerns are not specific to gold mining. Hazardous wastes are not expected to result in any environmental impacts at the mine site since their storage or disposal is carefully managed and regulated.

3.2.8 Sludges

The production, management and disposal of metal sludges produced in effluent treatment at gold mines appears to be of only minor environmental significance. The current practice for disposal of sludges in the tailings may raise some concern over long-term stability of the metals. However, the volume of sludge and quantity of metals contained in it is very small compared with the size and content of the tailings themselves. Thus, although it would appear prudent to consider sludge stability during planning for decommissioning, there appears to be little cause for concern.

3.2.9 Heap Leaching

Heap leaching of gold ores does not give rise to any major environmental questions. Two areas of potential environmental impact were identified, namely loss of leach solution by (a) seepage into ground water, and (b) dispersion into surrounding air by mist blowing. Experience with heap leaching in Canada is limited and more time will be required to evaluate the environmental significance of these potential effects. Currently, as long as monitoring programs are continued, there appears to be no cause for concern.

3.2.10 Air emissions

No major environmental impacts relating to air emissions from gold mine operations were identified. Indeed, there do not appear to be any airborne releases which might represent a potential hazard in any of the gold extraction processes identified by Environment House. The absence of information, and the fact that emissions would likely continue for the operational life of the mine, may indicate the need to assess the possible impacts of air emissions further. However, in the absence of any identifiable concern, this is obviously of low priority.

3.3 TECHNOLOGY-BASED OPPORTUNITIES

The previous section (Section 3.2) identified significant environment-related needs in four areas, namely:

(1) Decommissioning of the entire mine property;

(2) Effects monitoring in receiving water bodies;

(3) Production of non-toxic effluents; and

(4) Long-term stability of tailings.

This section describes and examines several possible responses to meeting these needs and reducing any associated environmental impacts. Because the goal of this study is to identify specific opportunities for CANMET, we have also included an assessment of the technical "competitors" who are developing solutions to these environment-related issues facing the gold mining sector.

3.3.1 Decommissioning of Entire Mine Property

There is a need to develop the technical framework that allows mine management to plan, implement and assess the decommissioning and close-out of the entire mine property -- mine, mill, tailings area, sludge ponds, waste rock piles, etc. This need could be satisfied by developing a series of technical guides or manuals which would:

- Set objective technical standards which are achievable and provide an adequate level of environmental protection over the long-term.
- Provide the predictive and evaluation tools that are required to determine what is necessary to protect the environment and what is achievable.

- Develop an evaluation process that allows decommissioning activities to be ranked according to their environmental significance so that resources can be appropriately allocated.

- Detail state-of-the-art examples and case histories of successful decommissioning plans, programs and results.

- Integrate existing knowledge from acid mine drainage and uranium tailings decommissioning programs into decommissioning planning in the gold sector.

- Focus research, development and demonstration efforts projects on decommissioning.

CANMET is extremely well positioned to respond to the need for a technical framework for decommissioning. Management and technical staff have the broad range of skills and experience -- in mining, mineral processing, tailings management and their associated environmental impacts -- that is required to address this need. Recent experience with the National Uranium Mill Tailings Program and the ongoing role with the MEND program further demonstrate CANMET's unique expertise in this area. Finally, CANMET has the laboratory facilities necessary to support the multipartite approach required to develop the guides and manuals which would be of use to industry and regulators alike.

Alternatively, the need for a technical framework for decommissioning could be met through the regulatory responsibilities of the provincial regulatory agencies such as the Ontario Ministry of Northern Development and Mines. However, this would require the regulations to include detailed and explicit standards on what is expected from mine decommissioning, and could result in up to 11 different decommissioning standards across Canada. In addition, this would likely result in an adversarial approach to regulation more typical of that used by US Environmental Protection Agency.

CONCLUSION:

A significant environmental issue associated with the gold mining sector is the need to carry out decommissioning activities that provide adequate long-term environmental protection. A technical framework must be developed so that mine operators can fulfil their responsibilities. Based on its extensive experience with all aspects of mining, CANMET is uniquely qualified to develop the guides and manuals that are the substance of such a framework.

3.3.2 Effects Monitoring in Receiving Water Bodies

If the goal of sustainable development is to be achieved in the gold mining sector, then discharges from mine operations should not reduce the future value of the environment. Specifically, effluent releases should be limited to those which are within the assimilative capacity of the receiving water body and do not impact on biota. However, realistic levels of potential contaminants in effluents cannot be determined until their effect on the receiving water body is known. Past practice probably provides an adequate data base to carry out this determination, although there is a need to develop the technical guidelines and methodology to monitor effects in downstream water bodies.

This technical requirement could be satisfied by implementing a program to monitor and assess the effects of gold mine discharges on receiving water quality. This program could comprise the following elements:

- Identify several water bodies that have received gold mine effluents for a number of years;
- Match the identified water bodies with similar unaffected water bodies;
- Develop sampling methodology and protocols to assess health and vitality of the receiving water bodies, including water chemistry, sediment contamination, fish, other biota, etc.;
- Determine discharge profiles for gold mine effluents including contaminant concentration, loading, duration, etc.;
- Develop modelling tools for matching effluent discharge parameters with the health of the receiving water body; and
- Develop an evaluation process for assessing the environmental significance of measured and predicted effects.

CANMET possesses some of the capabilities to implement such a program. For example, CANMET has the laboratory facilities and staff have detailed knowledge of and experience with analytical and sampling methodologies. However, such a program would also require expertise in biology, limnology and hydrology. These qualifications are held within organizations such as the Wastewater Technology Centre in Burlington, the Freshwater Institute in Winnipeg or the River Road Environmental Technology Centre in Ottawa. Because CANMET is interested in the application of technologies outside the plant wall but inside the property fence, the mandate of these other organizations may more closely match an environmental effects monitoring program.

The alternative to a broad coordinated program on effects monitoring is the case-by-case approach being followed by Ontario's Ministry of the Environment. As part of their approvals process, the MOE is requiring individual mine operators to carry out effects monitoring in the receiving water body. These private sector studies are obviously limited in scope and duration. In addition, this regulatory approach tends to favour the collection of large amounts of data with less emphasis being placed on evaluation and assessment.

CONCLUSION: **Environment effects monitoring is an important issue in the gold mining sector; the impacts on receiving water quality and aquatic biota have not been adequately determined. The skills and experience required to develop the guidelines and methodology for monitoring environmental effects are not well matched with those of CANMET staff.**

3.3.3 Production of Non-toxic Effluents

The production of non-toxic effluents from gold mines requires substantial removal or destruction of cyanide, metals, and ammonia. However, the removal of metals is closely related to cyanide treatment and the significance of ammonia has not been adequately quantified. Thus, efforts to improve gold mine effluent quality should initially focus on cyanide removal. Subsequently, an assessment of the need for treatment for metal removal can be made. Indeed, some current evidence suggests that metals may not be a concern if cyanide concentrations are sufficiently low. Development of ammonia treatment possibilities could be carried out simultaneously, although as noted previously, the initial focus should be on quantifying the extent and significance of the ammonia problem and determining how it is affected by cyanide removal processes.

The production of non-toxic effluents with respect to cyanide could be achieved by (a) development of a significantly improved treatment process, (b) recovery of cyanide from mill effluents, or (c) development of a zero effluent mill. Although implementation of any one of these may result in a non-toxic effluent, this goal could also be achieved by a combination of two or three options.

<u>Improved treatment processes</u>

Numerous processes for the destruction of cyanide in industrial effluent have been proposed and tested over the years. However, most of these have not proven successful for treating gold mine effluents. Those that are currently being used in the gold industry are listed below:[13]

- Natural degradation is used exclusively at about one half of Canada's gold mining operations. While capable of reducing cyanide to less than 0.1 mg/L in engineered systems, large ponds and very long holding times are required.
- The proprietary INCO SO_2/air oxidation process is used at 10 Canadian operations and is capable if reducing cyanide to less than 1 mg/L.
- Hydrogen peroxide oxidation is used at 13 Canadian operations and can reduce cyanide concentrations to less than 1 mg/L.
- The Golden Giant precipitation process is also a proprietary technique using ferrous sulphate and cupric sulphate to precipitate insoluble cuprous cyanide in conjunction with peroxide oxidation is used at one Canadian mine. Cyanide removal to 0.13 mg/L has been reported.[13]
- Alkaline chlorination is no longer used in Canada because of high reagent costs, concerns over handling of chlorine and the possibility of residual chlorine in treated effluent.
- The Homestake biodegradation process appears unsuitable for use in Canada because it requires a minimum of 10°C for efficient operation.

Most of the above processes have been investigated, developed, and used successfully by gold mine operators. The first three processes are commonly used in Canada, although none are capable of consistently producing non-toxic effluent. There has been extensive development work on these treatment technologies, and they are being continually improved. However, it is uncertain that the magnitude of improvement required to produce non-toxic effluents can be achieved. Instead, continuing development work is more productively directed towards process control improvements tailored to site-specific effluents.

Two other processes -- the Noranda SO_2 Process and Ferrous sulphide adsorption -- were tried in Canada but are no longer used. Neither of these two processes would seem to be capable of achieving the degree of cyanide destruction required to produce a non-toxic effluent. Other cyanide treatment processes which have been considered are as follows:

- Ozonation: Oxidizes cyanide to cyanate. This process has high operating costs and technical difficulties in full scale operation.
- Ferrous Iron Bisulphite Treatment: This process is based on conversion of cyanide to ferrocyanide and precipitation with iron. It also uses SO_2 or bisulphite but has apparently not been tested at pilot scale.
- Kastone® Peroxide Process: Oxidizes cyanide to cyanate but is expected to involve high operating costs.
- Activated Carbon Adsorption/Oxidation: Oxidizes cyanide to cyanate on an activated carbon substrate using a nickel or copper catalyst.

- Ion Flotation and Precipitate Flotation: Separates cyanides and complexes by

adsorption onto collectors or the formation of precipitates followed by conventional froth flotation.

- Ion Exchange: Cyanides and complexes are separated by adsorption to ion exchange resins.
- Electrochemical Destruction: Cyanides are electrolytically degraded at anodes of electrochemical cells.

None of these processes appear to have as much promise as the three processes currently in use in Canada. Thus, it is unlikely that any of them warrants the effort required to develop and test their capability to produce non-toxic effluent. Indeed, the prognosis for a new generation cyanide treatment technology capable of producing non-toxic effluents is poor.

We have not examined metal and ammonia effluent treatment processes in as much detail. However, as noted previously, the production of non-toxic effluents with respect to metals is closely linked with cyanide treatment. Although several metals removal processes may be applicable, it is difficult to assess their relevance until non-toxic levels of cyanide can be achieved.

The situation with ammonia is quite similar, although there does not appear to be an obvious treatment process capable of reducing ammonia concentrations to the anticipated non-toxic levels. However, as is the case with metals in gold effluents, the primary need appears to be an assessment of the extent and significance of ammonia concentrations and their relationship to cyanide toxicity.

Thus, if gold mine effluents are to be made non-toxic, new or significantly improved treatment processes for cyanide, ammonia and, possibly, metals are required. A major process development program would address this need. A number of research and development organizations in Canada appear to be better equipped than CANMET to implement such a program. For example, INCO Limited has been extensively involved with the development and implementation of one current state-of-the-art treatment process for cyanide removal, and the Wastewater Technology Centre in Burlington, has a long history of process development work on gold effluents. Either of these organizations have the skills and experience to carry out process development work, if effluent treatment is the chosen means of producing non-toxic effluents. We suspect, however, that technological efforts could be more productively focused on other approaches. Effort would be better directed towards the optimization of the existing processes and looking for other ways of producing non-toxic effluents.

Cyanide Recovery Processes

Recovery and reuse of cyanide from tailings and mill solutions, rather than its destruction in effluent treatment plants, is conceptually attractive and may be an important step in producing non-toxic effluents. Effluents from cyanide recovery processes are expected to have very much lower cyanide concentrations than current

tailings or mill solutions and natural degradation in the tailings area could be expected to lower these concentrations further. Thus, a cyanide recovery process might result in the discharge of a final effluent which was essentially cyanide-free.

A number of cyanide recovery technologies have or are being tested for possible use in gold mine effluent treatment. Three of these are based on the AVR (Acidification/Volatilization/Re-neutralization) process. The waste cyanide is acidified to spring off hydrogen cyanide gas which is then scrubbed and collected in a caustic solution and the cyanide is recycled. The effluent stream from this is low in cyanide and could be discharged to the environment with little or no treatment. Metal ferrocyanide impurities are removed and disposed of as solids.

The AVR variations described in the literature are:

- The CANMET AVR process: Effluent streams are treated directly with acid. Studies showed final effluent quality of less than 0.1 ppm free cyanide is possible. This process, which is not suitable for slurries, was used at one Canadian gold mine up to 1978.

- The CY-TECH process: Cyanide is first collected on an ion exchange resin, then eluted prior to AVR. Indications are that as a stand-alone system, it is not capable of meeting effluent guidelines for cyanide. It has not been tried at full scale in Canada and cannot be used on slurries.

- CYANOSAVE™ Technology: Cyanide is first collected on special glass beads (VITROKELE® 912) then eluted for AVR. This process, which has been Pilot Demonstrated in Australia, can be used on slurries and can produce effluents with cyanide of less than 0.5 mg/L. A pilot scale test is scheduled in Ontario during early 1991.

One other recovery process being evaluated for use is the CELEC cyanide regeneration system. This is based on an electrolytic process which converts all cyanide compounds to free cyanide for direct recycle and is especially suited to processes in which copper is a concern. The copper is recovered as a metal. Indications are that there would be no discharge to the environment. Slurries must be clarified prior to treatment.

Thus, cyanide recovery processes appear feasible although their limited use suggests a need for process development and demonstration on specific tailings or mill solutions. This includes addressing possible operational difficulties such as safety concerns for hydrogen cyanide or the relatively high operating costs. In addition, there is a need to assess the performance of recovery processes in conjunction with natural degradation and to evaluate their ability to produce non-toxic effluents. These needs could be satisfied by pilot scale demonstration of a recovery process and examination of its ability to result in final effluents that are sufficiently low in cyanide to be non-toxic.

This need may be met by the Ontario Ministry of the Environment's planned demonstration of the CYANOSAVE™ process scheduled for early this year. It is not known whether the goals of the planned demonstration are similar to those outlined above. Further, the capital and operating costs of any recovery process, and the current low price of gold, indicates wide-spread implementation of this new technology may be delayed even if the demonstration is successful. It is suggested that CANMET review the performance of this test before making any decision on implementing additional work on cyanide recovery processes. However, because of the likely continuing interest in cyanide recovery processes, CANMET should maintain its expertise and awareness of developments in this area.

"Zero effluent" mill

A "zero effluent" mill would require that either all flows to receiving water bodies are eliminated or that contaminant concentrations are reduced to their natural level in upstream water. Achieving this goal is difficult in the Canadian climate where precipitation exceeds evaporation, and significant evaporation is limited to the warmer months of the year. Despite these conceptual and practical difficulties, the environmental benefits of a "zero effluent" mill warrant its consideration as an alternative to the complex treatment technologies that may be required to respond to increasingly stringent effluent standards. Thus, there is an opportunity to determine if a zero "effluent mill" is possible in the Canadian environment.

A combination of processing innovations, effluent treatment technologies and water management practices will be required to achieve the goal of zero effluent. Gold mines currently practice substantial water recycling and reuse, and many mines release effluent from their tailings areas during only a few months of the year. The obvious complexity of this issue requires careful assessment and evaluation of its technical and economic feasibility.

CANMET is uniquely positioned to respond to this technical opportunity by initiating a study aimed at identifying factors such as (a) the current limitations on water recycling, (b) the need for bleed stream treatment, and (c) the potential for improved water management in the tailings area. Specifically, the technical and economic feasibility should:

- Develop a water balance for a typical gold mill and tailings management area;
- Identify the technical barriers to water recycling and reuse;
- Identify possible technical solutions and determine their potential for implementation; and

- Estimate the capital and operating costs of implementation.

CANMET possesses the capabilities to carry out such a feasibility study. CANMET management and staff have the necessary metallurgical skills as well as experience with effluent treatment processes and tailings management. Furthermore, since achieving a "zero effluent" mill will require technological developments in both processing and tailings management, this project fits well with CANMET's goal of identifying opportunities for technological developments outside the plant but inside the property fence.

We are aware of no other group with the combination of skills, resources and record of cooperation with the mining industry that is required to successfully carry out this complex feasibility assignment.

CONCLUSION: **Three approaches might be used to produce non-toxic gold mine effluents: (a) new or improved treatment processes, (b) cyanide recovery, or (c) a "zero effluent" mill. CANMET uniquely possesses the skills and experience to carry out a research program aimed at determining the technical and economic feasibility of a "zero effluent" mill, which would obviate the need for (a) or (b).**

3.3.4 Long-term stability of tailings

To a large extent, this issue is addressed in the section on decommissioning (see Section 3.3.1) and the environmental concerns would be covered by the suggested technical framework for decommissioning. However, we believe there are sufficient potential environmental concerns related to the long-term stability of tailings to warrant consideration in its own right. Specifically, little is known about the environmental consequences of erosion or seepage associated with gold tailings.

The MEND program is directed towards acid generating tailings. However, gold tailings in Ontario do not appear to generate acid and so would be excluded from MEND's research and development projects. Thus, there is a need for a research program aimed at determining and quantifying these impacts. This could be satisfactorily addressed by implementing a field and laboratory research project. This research project should include:

- Identification of several typical gold tailings areas based on factors such as age, geography, volume of tailings, geology, etc.;

- Field and laboratory studies to identify and determine the concentration of potentially mobile contaminants within the tailings;

- Investigation of the natural degradation and assimilative processes for potential contaminants within the tailings basin; and

- Development of the predictive tools to determine the anticipated long-term environmental loadings of contaminants from tailings areas.

CANMET possesses the technical skills and resources to implement this research program. CANMET staff have both managed and carried out field investigations on tailings for many years. In particular, experience with uranium tailings research projects, the National Uranium Tailings Program and the MEND program would be directly applicable to this project. In addition, CANMET's mineralogical expertise would be extremely relevant.

Environment Canada's National Hydrology Research Institute in Saskatoon conducts field and laboratory investigations on ground water contamination. However, to the best of our knowledge that organization has not had much involvement with tailings-related issues. Thus, CANMET is probably better positioned to implement a tailings research program.

CONCLUSION: **Gold tailings are generally not acid generating and so not a focus of the MEND program. Given this absence of environmental research, field and laboratory programs are required to identify and assess any long-term environmental impacts of gold tailings. CANMET has the necessary skills and experience to carry out this program.**

3.4 RECOMMENDATIONS

The gold sector of Canada's mining industry provides a number of opportunities for CANMET to initiate research programs that respond to environmental concerns deemed to be important in the regulatory and scientific literature. Furthermore, because of its skills, experience and technology base, CANMET is uniquely qualified to exercise this leadership on behalf of the Government of Canada and in consultation with industry.

While several opportunities were identified in the previous section, the most pressing requirements relate to (a) the decommissioning of closed out mining operations, (b) the production of non-toxic mill effluents and (c) the environmental consequences of gold tailings. Accordingly, Environment House Limited recommends:

3.4.1 Decommissioning

That CANMET examine the feasibility of developing a decommissioning program of strategic importance within its environment-related research.

That the goal of this decommissioning program is the development of the technical framework--the guidebooks and manuals--for decommissioning, a framework that can be used with confidence by mine operators, consultants, government, and the financial community to efficiently and effectively mitigate the long-term environmental consequences of mine closures.

That CANMET determine the scope of such a program and its relevance to CANMET by (a) assessing the regulatory-driven need for decommissioning standards (b) identifying significant technical problems, and (c) evaluating the opportunities for technically-based solutions.

Specifically, CANMET should:

Survey and assess the regulatory requirements and industrial practices associated with the decommissioning of mines in all Canadian jurisdictions, as well as leading U.S. jurisdictions.

Identify those decommissioning challenges and activities that are common to all sectors of Canada's mining industry.

Identify those decommissioning problems and activities that vary substantially, according to the type of mineral or metal that is mined and processed.

3.4.2 Mill Effluents

That CANMET direct some of its metallurgical-based research efforts towards developing "zero effluent" milling processes.

That initially this effort focus on a concept of a "zero effluent " gold mill. The study should identify the technical and financial barriers, as well as providing qualitative assessments of the benefits.

That CANMET subsequently assess the applicability of "zero effluent" milling to other sectors of the Canadian mining industry. Of particular interest is the role this concept might have as a route to achieving sustainable development in Canada's mining industry.

That CANMET spearhead a detailed technical and economic feasibility study of "zero effluent" milling in Canada if the above concept studies indicate it is viable.

3.4.3 Gold Tailings

That CANMET review its existing mine tailings research programs to determine whether or not they address the environmental issues related to gold tailings.

That this review identifies any potential long-term environmental problems associated with gold tailings and their similarities and differences with other mine tailings in Canada.

That CANMET initiate field and laboratory studies to address any environmental problems associated with gold tailings such as the fate and mobility of cyanide in soils.

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APPENDIX

APPENDIX 1: ONTARIO GOLD MINES – 1989

Area	Company	Location	1988 Production (kilograms)*
Timmins–Kirkland Lake			
	American Barrick Resources Corp.	48 km N of Kirkland Lake	744
	Canamax Resources Inc.	30 km E of Timmins	767
	Eastmaque Gold Mine Inc.	Kirkland Lake	428
	Falconbridge Gold Corp	Timmins (Two mines)	1,926
	Royal Oak Resources Ltd.	Timmins	3,646 **
	Deak Resources Corporation	Virginiatown	1,082
	Lac D'Amiante Du Québec Limitée	35 km E of Timmins	337
	Lac Minerals Ltd.	Kirkland Lake	2,437
	Placer Dome	Timmins	3,410
	INCO Limited	16 km E of Kirkland Lake	131
	St. Andrews Gold Fields Limited	5 km E of Timmins	– ***
			14,908
Hemlo–Wawa			
	Canamax Resources Inc.	50 km NE of Wawa	173
	Corona Corporation	Hemlo	11,787
	Corona Corporation	Wawa	1,203
	Flanigan–McAdam Resources Inc	Hemlo	– ***
	Hemlo Gold mines Inc.	Marathon	10,498
	Muscocho Exploration Ltd.	Wawa	194
	Teck–Corona Corp Joint Venture	Hemlo	6,745
			30,600
Red Lake–Pickle Lake			
	Bond Gold Canada Inc.	Pickle Lake	507
	Dickenson Mines Limited	Red Lake	2,197
	Placer Dome	Red Lake	7,433
	Placer Dome	Pickle Lake	– ***
			10,137
Other			
	Placer Dome	Detour Lake	3,407
	Orofino Resources Limited	Sudbury	147
	Ateba Mines Inc.	Thunder Bay	44
	Mattabi Mines Limited	Ignace	157
			3,755
Production as by–product of base metal operations.			3,158
		Total	62,558

* From Canadian Mining Journal – March 1990.

** Includes production from ERG Resources Inc.

*** Started Production in 1989.

GOLDMINE.WK3